TMDL for *Escherichia coli (E. coli)* in the North Fork Virgin River Watershed

Prepared for:
US Environmental Protection Agency, Region 8

Prepared by:
Utah Department of Environmental Quality
Division of Water Quality

Amy Dickey, Project Manager
Carl Adams, Project Supervisor

October 2017

Utah Department of Environmental Quality
Division of Water Quality
Water Quality Protection Section
Lower North Fork Virgin River TMDL

Waterbody ID	UT15010008-015
Location	North Fork Virgin River -1 North Fork Virgin River And Tributaries From Confluence With East Fork Virgin River To Deep Creek Confluence
Pollutants of Concern	*Escherichia coli (E. coli)*
Impaired Beneficial Uses	Class 2A: Frequent Contact
Current Loading (For July, the month with the largest necessary reduction) Loading Capacity (TMDL) Load Reduction	1.71X10^{11} organisms/day 1.52X10^{11} organisms/ day 11%
Wasteload Allocation Load Allocation Margin of Safety (10% of Loading Capacity)	0 organisms/ day 1.52X10^{11} organisms/ day 1.69X10^{10} organisms/ day
Defined Targets/Endpoints	1. For recreation seasons with >5 collection events in any recreation season, no more than 10% of samples collected from May 1st through October 30th should exceed 409 MPN/100 mL. 2. For recreation seasons with ≥5 collection events, no 30-day interval geometric means with 5 or more samples should exceed 126 MPN/100 mL. 3. For recreation seasons with ≥10 collection events, the geometric mean of all samples should not exceed 126 MPN/100 mL.
Implementation Strategy	Stakeholders will employ an adaptive management approach to address all anthropogenic sources of *E. coli* loading with focus on improvements in pasture irrigation and grazing management. TMDL will be re-evaluated within 10 years.

Utah Department of Environmental Quality
Division of Water Quality
Water Quality Protection Section
Upper North Fork Virgin River TMDL

Waterbody ID	UT15010008-013
Location	North Fork Virgin River-2 North Fork Virgin River And Tributaries From Deep Creek Confluence To Headwaters
Pollutants of Concern	*Escherichia coli (E. coli)*
Impaired Beneficial Uses	Class 2A: Frequent Contact
Current Loading (For July, the month with the largest necessary reduction) Loading Capacity (TMDL) Load Reduction	$1.01X10^{11}$ organisms/day $2.4X10^{10}$ organisms/day 76%
Wasteload Allocation Load Allocation Margin of Safety (10% of Loading Capacity)	0 $2.4X10^{10}$ organisms/day $2.66X10^{9}$ organisms/day
Defined Targets/Endpoints	1. For recreation seasons with >5 collection events in any recreation season, no more than 10% of samples collected from May 1st through October 30th should exceed 409 MPN/100 mL. 2. For recreation seasons with≥5 collection events, no 30-day interval geometric means with 5 or more samples should exceed 126 MPN/100 mL. 3. For recreation seasons with ≥10 collection events, the geometric mean of all samples should not exceed 126 MPN/100 mL.
Implementation Strategy	Stakeholders will employ an adaptive management approach to address all anthropogenic sources of *E. coli* loading with focus on improvements in pasture irrigation and grazing management. TMDL will be re-evaluated within 10 years.

EXECUTIVE SUMMARY

This document provides a review of available *E. coli* data for the North Fork Virgin River to assess and restore the recreational beneficial use for the river as defined by Utah Administrative Code R317-2-6 and the Clean Water Act (CWA). After reviewing available data for North Fork Virgin River, potential sources are identified and the critical period for load reductions is defined and discussed. This watershed is a high priority for *E. coli* TMDL development by the Utah Division of Water Quality (DWQ) due to the large number of people recreating in the river in and near Zion National Park.

Water quality concerns in the North Fork Virgin River were first identified in a previous study conducted by Zion National Park staff that showed high fecal coliform levels in 2000. Since then, hundreds of water quality samples have been gathered by the Utah Division of Water Quality (DWQ), Zion National Park and Kanab Bureau of Land Management to understand the nature and extent of the problem.

E. coli data have been collected at multiple sample sites throughout the Upper North Fork Virgin River watershed on a monthly basis throughout the recreation season of May through October. Exceedances of the standard appear to be primarily driven by return flows from flood irrigated pastures that are actively grazed by cattle. Irrigation takes place from June through October making that the critical period for bacteria loading to the river.

Changes in grazing and irrigation water management in 2016 and 2017 have resulted in decreased bacteria concentrations in the river. With continued proper management and implementation of additional best management practices identified in this document DWQ believes water quality standards can be met and maintained.

TABLE OF CONTENTS

FIGURES

TABLES

MAPS

1.0 INTRODUCTION AND BACKGROUND

1.1 Purpose

This document represents the total maximum daily load (TMDL) analyses of two impaired assessment units of the North Fork of the Virgin River Watershed in fulfillment of Clean Water Act (CWA) requirements. A TMDL analysis determines the amount of an identified pollutant (i.e., the load) that a waterbody can receive while preserving its beneficial uses and state water quality standards. Once the pollutant loads have been identified, controls are implemented to reduce those loads until the waterbody is brought back into compliance with water quality standards. Upon completion of the TMDL analysis, it is submitted to the Utah Water Quality Board and the U.S. Environmental Protection Agency (EPA) for approval.

The Federal Water Pollution Control Act is the primary federal legislation that protects surface waters such as lakes and rivers. This legislation, originally enacted in 1948, was expanded in 1972 and became known as the CWA. The purpose of the CWA is to improve and protect the physical, chemical, and biological integrity of the nation's waters. The CWA requires EPA or delegated authorities such as states, tribes, and territories to evaluate the quality of waters, establish beneficial uses, and define water quality criteria to protect those uses. Section 303(d) of the CWA requires that, every 2 years, each state submit a list of waterbodies that fail to meet state water quality standards to the EPA. This list is the "303(d) list," and waterbodies identified on the list are referred to as "impaired waters." For impaired waters, the CWA requires a TMDL analysis for each pollutant responsible for impairment of its designated use(s).

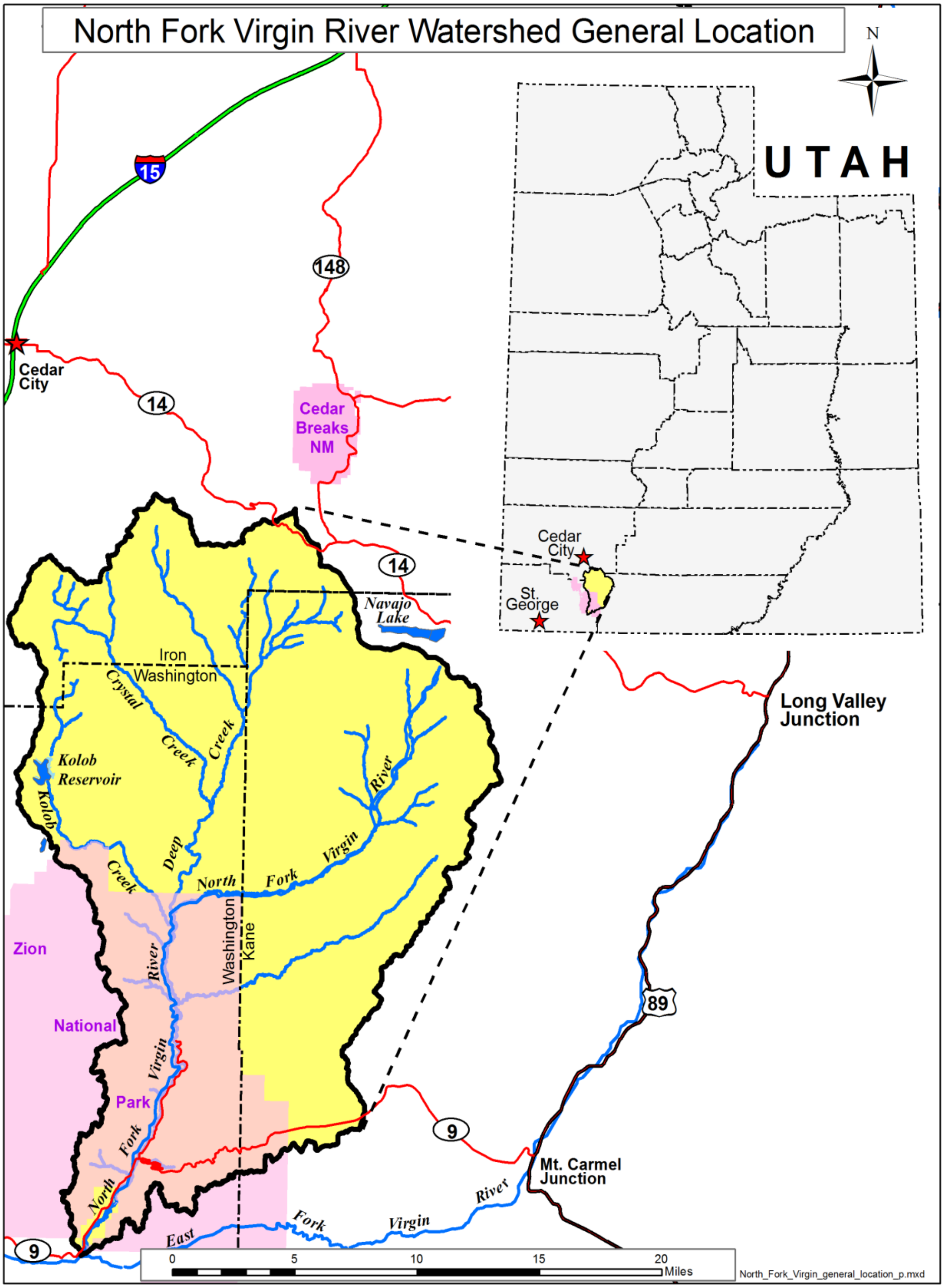
The Utah Department of Environmental Quality's Division of Water Quality (DWQ) collects biological and water quality data to evaluate the quality of the waters of the State of Utah. Based on this assessment, the North Fork of the Virgin River was included on the State of Utah's 303(d) list in 2010 for exceedances in *Escherichia coli* (*E. coli*). This report defines the TMDL and water quality targets that, when attained, will bring the river into full support of its beneficial uses.

E. coli is a species of fecal coliform bacteria that is specific to fecal material from warm-blooded animals and is considered the best indicator of human health risk in surface waters (EPA 2012). Violations of the water quality standard have the potential to affect human health because the North Fork of the Virgin River is used for irrigation, recreation, and fishing. Impairment of waterbodies in the watershed is cause for concern because of the potential human health risk, degradation of aquatic life, and implications for future management of agricultural practices and local communities. Common sources of *E. coli* include waste from livestock and wildlife as well as input from faulty septic systems.

1.2 Study Area Boundary

The North Fork Virgin River Watershed is located on the Colorado Plateau in Southwest Utah (Figure 1). It drains approximately 360 mi^2 (230,390 acres). The watershed is bounded by the Markagunt Plateau to the north, the Kolob Plateau to the West and Clear Creek Mountain to the east.

The North Fork Virgin River originates at Cascade Falls, where water from nearby Navajo Lake flows over one mile underground through karsted limestone rock formations before reappearing at the falls at approximately 9,000 feet in elevation. The river then flows downstream through aspen and ponderosa pine forest for approximately 16 miles until entering Zion National Park. The North Fork Virgin River continues through the Park for several miles and combines with Deep Creek, Kolob Creek and several other tributaries to flow through the famous Zion Narrows. The river flows a distance of 25 miles from Cascade Falls to the confluence with the East Fork Virgin River in the town of Springdale.



Map 1. Location of North Fork Virgin River Watershed.

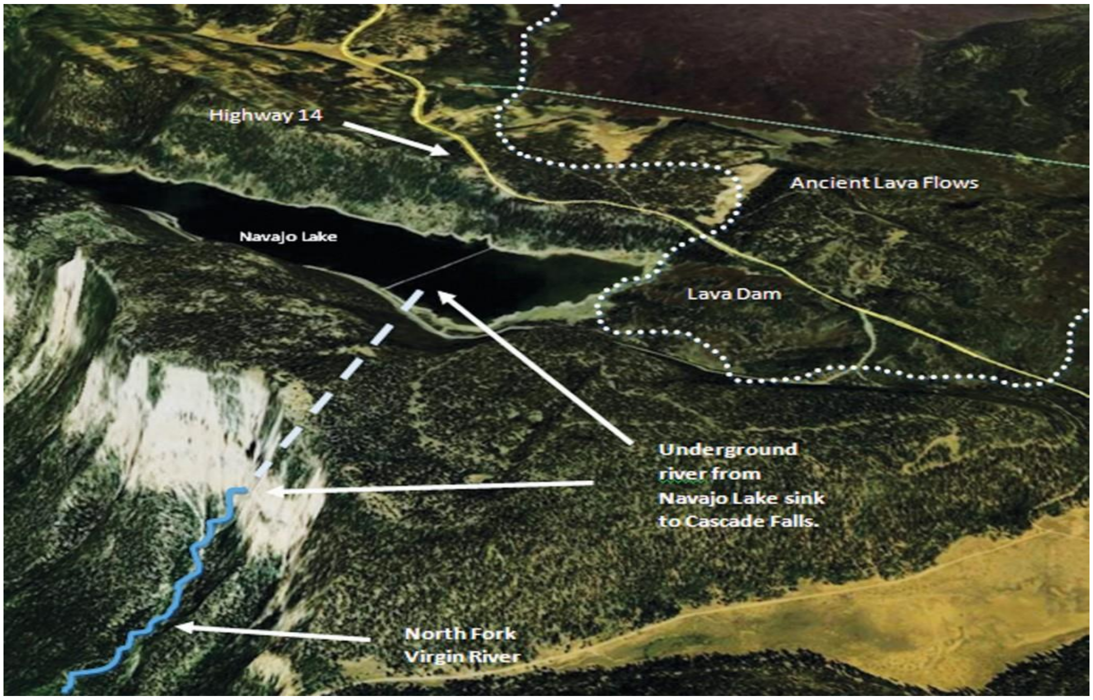


Figure 1: North Fork Virgin River headwaters near Cascade Falls (Image from Lance Weaver, UGS)

Figure 2: Cascade Falls discharges from the limestone beds of the Clarion Formation. August 2017

2.0 WATER QUALITY STANDARDS

2.1 Total Maximum Daily Load (TMDL) Definition

A TMDL is composed of the sum of individual wasteload allocations (WLAs) for point sources and load allocations (LAs) for nonpoint sources and natural background levels. In addition, the TMDL must include a margin of safety (MOS), either defined implicitly or explicitly, that accounts for the uncertainty in the relationship between pollutant loads and the quality of the receiving waterbody. Conceptually, this definition is denoted by the equation:

$$\mathbf{TMDL = \sum WLAs + \sum LAs + MOS.}$$

Subsequent to 303(d) listing, the State is required to develop a Total Maximum Daily Load (TMDL) to reduce pollutant levels in impaired waters. A TMDL is a calculation of the maximum amount of a pollutant that a waterbody can receive on a daily basis and still meet water quality standards. The TMDL process consists of the following steps: 1) Review existing water quality data, 2) Identify sources and causes of pollutants, 3) Identify water quality goals, 4) Establish the amount of pollutant that can be allowed in total, 5) Allocate allowable pollutant loads to the various sources, 6) Identify and implement measures to achieve and maintain water quality standards, and 7) Monitor to assure that goals are met. The TMDL process generally results in load allocations to each pollutant contributor that may result in regulatory controls and mandates.

2.2 Impairment of North Fork Virgin River

The river was 303(d) listed for high *E. coli* levels in 2010. Monitoring efforts by DWQ, Zion National Park and Kanab Bureau of Land Management indicate that the primary source of nonpoint source pollution in the river is irrigation return flows from flood irrigated pastures that are grazed throughout the summer months. Evidence for this includes: (1) high levels of *E. coli* in the return flow water sampled where it enters the river, and (2) a substantial reduction in *E. coli* levels measured in the river when irrigation watering is interrupted, even though cattle remain on the pastures. Other potential sources include improper human waste disposal (residential and recreational) and fecal contamination from the abundant wildlife present throughout the watershed.

2.3 Water Quality Standards and TMDL Target

The purpose of a TMDL water quality study is to establish the water quality goals and endpoints that will meet water quality standards and restore an impaired waterbody's designated beneficial uses. One of the primary components of a TMDL is the instream numeric target to evaluate attainment of water quality goals. Instream numeric targets, therefore, represent the water quality goals to be achieved by reducing pollutant loads specified in the TMDL. Numeric water quality targets associated with North Fork Virgin River are listed in Table 3. The targets allow for a comparison between current instream conditions and those required to support its beneficial uses. The targets are established on the basis of numeric criteria from state water quality standards.

Due to the high degree of variability observed in *E. coli* levels in natural waters, the geometric mean, a type of average, of several samples provides a superior measure of the risk of disease. The geometric mean indicates the central tendency or typical value of a set of numbers by using the product of their values (as opposed to the arithmetic mean which uses their sum). Use of a geometric mean standard is recommended for environmental assessment because it lessens the bias of infrequent values that are very high.

2.4 Overview of 303(d) List

DWQ segments waters into relatively homogenous units called Assessment Units (AUs). The North Fork Virgin River is split into two assessment units. The physical, chemical, and biological conditions of the waters within an AU are more similar to each other than adjacent AUs. Environmental factors such as flow, channel morphology, substrate, riparian condition, adjoining land uses, confluence with other waterbodies, and potential sources of pollutant loading are considered when delineating AUs.

Both North Fork Virgin River AUs are impaired for *E. coli* and temperature. This TMDL will focus only on the *E. coli* impairment. The temperature listing was prioritized by DWQ as less critical and will be addressed in the future.

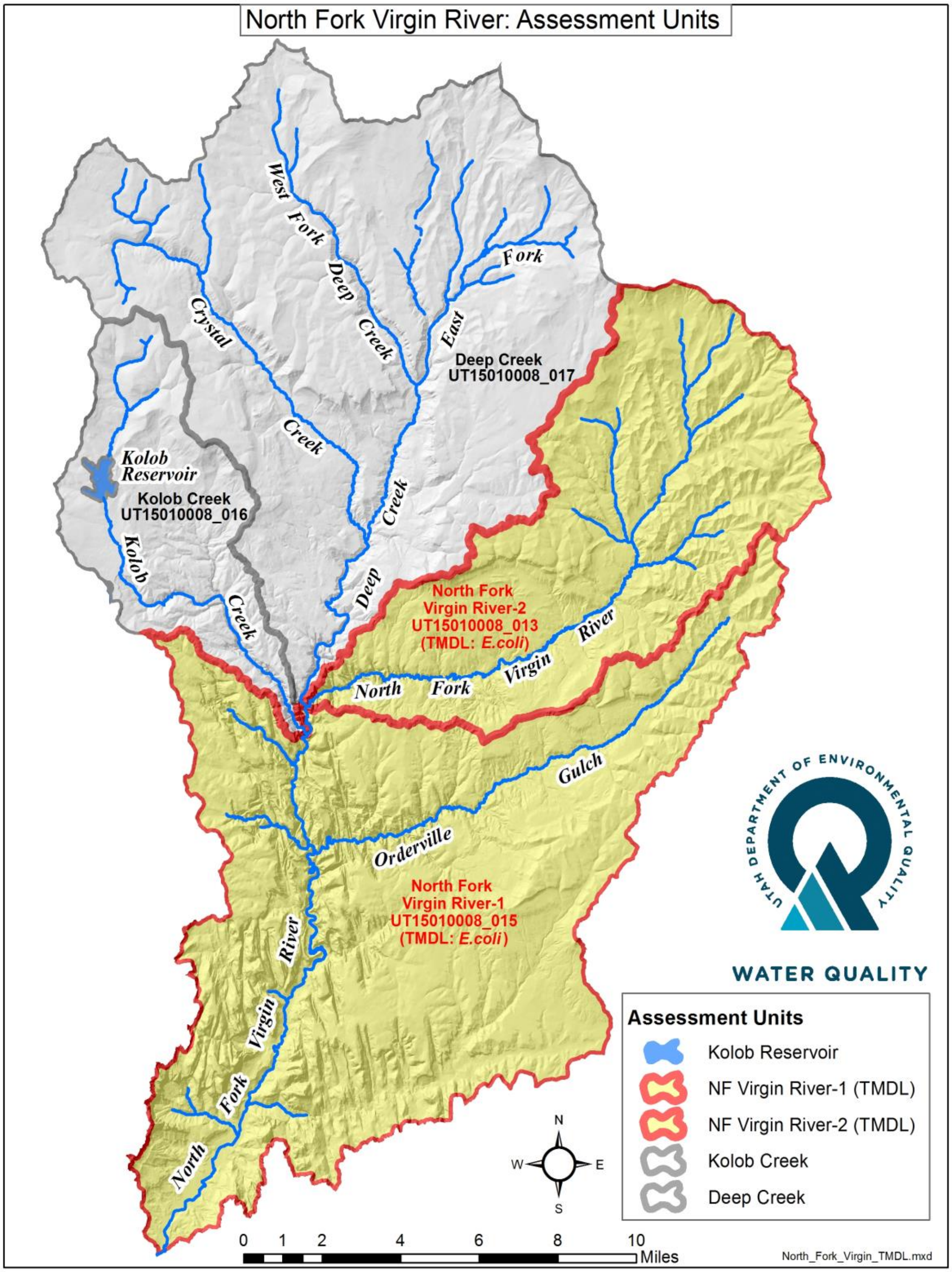
Since 2006, Utah has used *Escherichia coli (E. coli)* instead of Fecal Coliform as the indicator species for pathogens as it provides a more accurate representation of the health threat posed by pathogenic contamination. The beneficial use that is impaired for *E. coli* is frequent primary contact recreational use such as swimming (Class 2A). While full immersion is practiced by a minority of people, the very large overall number of people recreating indicates that a substantial number are engaging in primary contact activities.

Name	Waterbody ID	Designated Uses
North Fork Virgin River And Tributaries From Confluence With East Fork Virgin River To Deep Creek Confluence	UT15010008-015	Domestic water source (1C) Frequent primary contact (2A) Cold water fishery and other aquatic life (3A) Agricultural uses (4)
North Fork Virgin River And Tributaries From Deep Creek Confluence To Headwaters	UT15010008-013	Domestic water source (1C) Frequent primary contact (2A) Cold water fishery and other aquatic life (3A) Agricultural uses (4)

Table 1. Designated Uses for the North Fork Virgin River watershed.

Assessment Unit Description	Cause of Impairment	Impaired Beneficial Use	Year 303(d) Listed
North Fork Virgin River And Tributaries From Confluence With East Fork Virgin River To Deep Creek Confluence	Pathogens (*E. coli*)	2A: Frequent primary contact	2014
North Fork Virgin River And Tributaries From Confluence With East Fork Virgin River To Deep Creek Confluence	Temperature	3A: Cold water fishery and other aquatic life	2010
North Fork Virgin River And Tributaries From Deep Creek Confluence To Headwaters	Pathogens (*E. coli*)	2A: Frequent primary contact	2010
North Fork Virgin River And Tributaries From Deep Creek Confluence To Headwaters	Temperature	3A: Cold water fishery and other aquatic life	2014

Table 2. Classification of Impaired Waters in the North Fork Virgin Watershed.



Map 2: North Fork Virgin River Watershed Assessment Units

2.5 Parameter of Concern (*E. coli*)

To ensure the protection of public health, routine monitoring of surface waters and assessment programs are needed. For Utah's bacteriological monitoring program, surface waters are monitored for pathogens that originate from fecal pollution from both human and animal waste. It is not feasible to monitor for all pathogens in water, but by analyzing for certain indicator organisms, it is possible to assess potential health risks. Following the Environmental Protection Agency (EPA) guidelines, Utah samples for *E. coli* concentrations in surface waters.

The use of indicator organisms as a means of assessing the presence of pathogens in surface waters has been adopted by the World Health Organization, EPA, and the European Union. *E. coli* are the most abundant coliform bacteria present in human and animal intestines numbering up to 1 billion organisms per gram of feces. They are the only true fecal coliform bacteria in that their presence can be exclusively attributed to a fecal origin. The presence of *E. coli* in water is a strong indication of recent sewage or animal waste contamination. Common fecal contamination sources include failing septic systems, leaking sewer lines, grazing pastures, confined feedlots, wildlife, and dog parks (Benham, 2006). Pathogenic bacteria are washed into surface waters during rainfall or snowmelt or deposited directly in the water and pose a threat to human health through incidental ingestion or contact with broken skin.

2.6 Applicable Water Quality Standards

Under the Clean Water Act (CWA), every state must adopt water quality standards to protect, maintain, and improve the quality of surface waters. These standards represent a level of water quality that will support the Clean Water Act's goals of "swimmable/fishable" waters. Water quality standards consist of three major components:

- Beneficial uses reflect how humans can potentially use the water and how well it supports those uses. Examples of beneficial uses include aquatic life support, agriculture, drinking water supply, and recreation. Every waterbody in Utah has designated uses; however, not all uses apply to all waters.
- Criteria express the condition of the water that is necessary to support designated beneficial uses. Numeric criteria represent the maximum concentration of a pollutant that can be in the water and still support the beneficial use of the waterbody. Narrative criteria state that all waters

must be free from sludge, floating debris, oil/scum, color and odor producing materials, substances that are harmful to human, animal, or aquatic life.

- Utah's antidegradation policy (UAC R317-2-3) establishes situations under which the state may allow new or increased discharges of pollutants, and requires those seeking to discharge additional pollutants to demonstrate an important social or economic need through the Utah Pollutant Discharge Elimination System (UPDES) permitting process.

The Utah Water Quality Board (UWQB) is responsible for establishing the water quality standards that are then enforced by the Utah Department of Environmental Quality, Division of Water Quality. Utah has numeric criteria for *E. coli* found in Utah Administrative Code, Standards of Quality for Waters of the State (UAC R317-2). These criteria vary based on the beneficial use assignment of the waterbody. Table 3 summarizes the *E. coli* standards pertaining to the 303(d) listed segments in the North Fork Virgin River watershed.

Designated Use	**Description**	***E. coli* Geometric Mean (MPN*/100 mL)**	***E. coli* Not to Exceed (MPN*/100 mL)**
2A	Frequent Primary Contact	126	409

Table 3. Water Quality Standards for Impaired Waters in the North Fork Virgin River Watershed.
*MPN/100 mL= Most Probable Number [of colonies] per 100 mL water

Utah has two recreational beneficial use categories, frequent contact recreation (2A) with more stringent criteria for uses such as swimming, and infrequent contact recreation such as boating or wading (2B). The *E. coli* numeric standard for 2A waters states that a sample may not exceed 126 MPN per 100 mL as a 30-day geometric mean and a maximum of 409 MPN per 100 mL in more than 10% of samples collected during the recreation season. The 30-day geometric mean is based on no less than 5 samples collected more than 48 hours apart within 30 days.

2.7 Utah's Listing Methodology

Surface waters designated as having a 2A recreational use in Utah are assessed for *E. coli* using the water quality standards (Table 3) and the assessment methodology presented below.

The following rules provide an interpretation of Utah's *E. coli* criteria, depending on the number of samples collected during the most recent six years of sampling. Assessment Units (AUs) that fail to meet any of these criteria will be included on Utah's 303(d) list of impaired waters; however, exceptions may be made to these rules if a single collection event represents an outlier that biases results:

- Scenario A: Seasonal assessment against maximum criterion.
  For each AU with >5 collection events in any recreation season, no more than 10% of samples collected from May 1st through October 30th should exceed 409 MPN/100 mL for 2A waters or 668 MPN/100 mL for 1C/2B waters throughout the most recent six years.

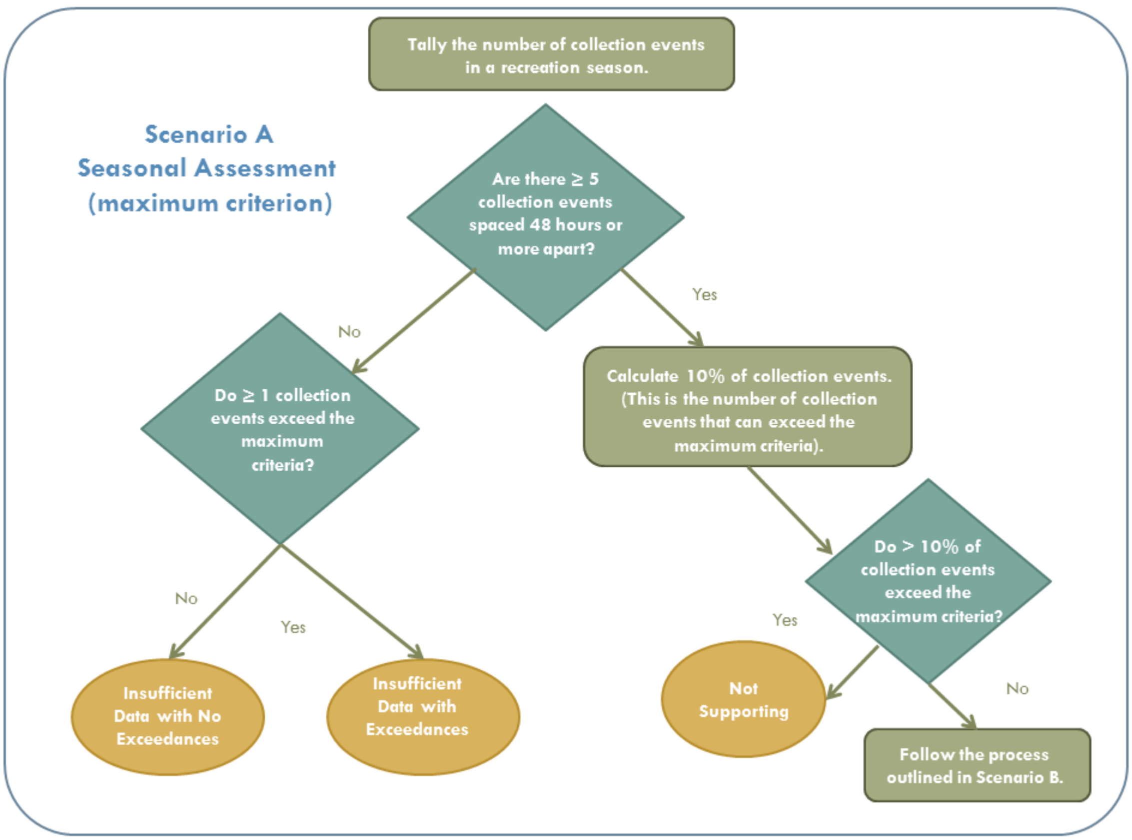


Figure 3: Seasonal assessment against maximum criterion

If less than 10 percent of collection events exceed the maximum criterion, the site is then assessed using the 30-day geometric mean criterion (Fig. 4). In order to assess against the 30-day geometric mean criterion directly, there must be a minimum of five collection events in 30 days, with at least 48 hours between collection events. This ensures that collection events are adequately spaced and are representative of ambient conditions.

- Scenario B: 30-Day geometric mean assessment.
  For each AU with ≥5 collection events in any recreation season, no 30-day interval geometric means should exceed 126 MPN/100 mL for 2A waters or 206 MPN/100 mL for 1C/2B waters throughout the most recent six years.

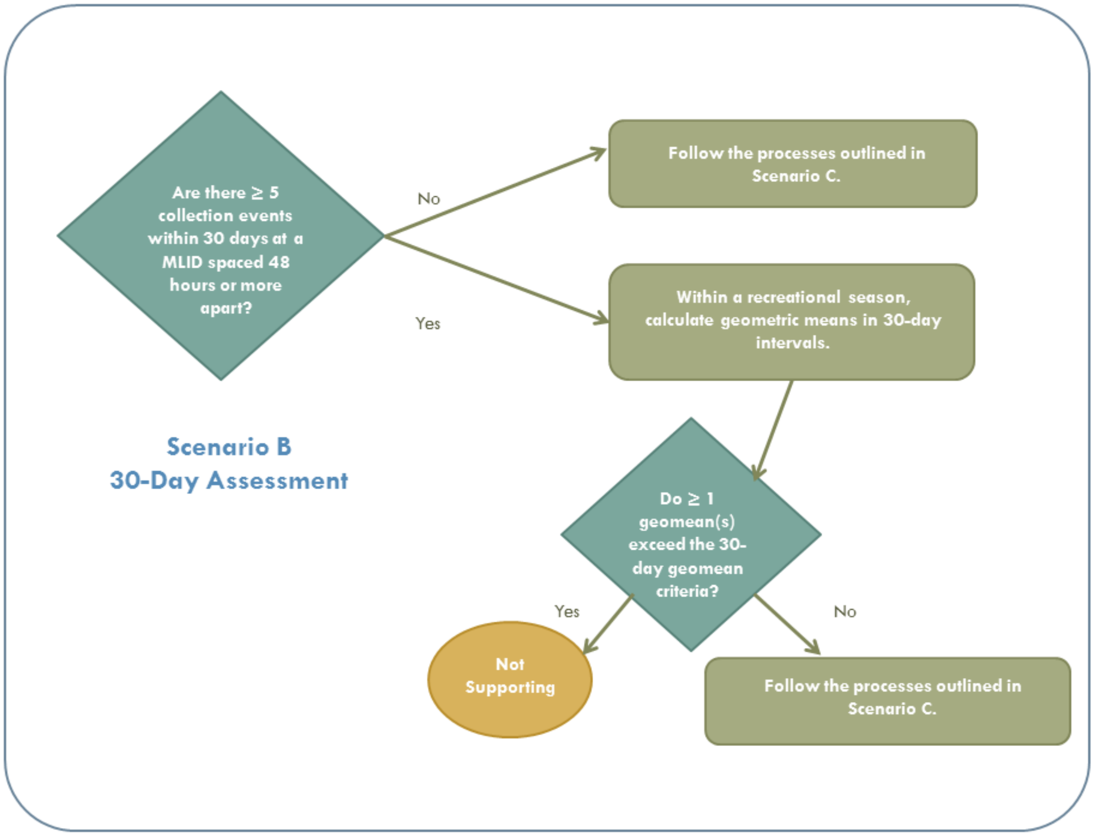


Figure 4: 30-day assessment against geometric mean

If adequate (at least five samples) and/or representative data spaced by at least 48 hours are not available to assess against the 30-day geometric mean, DWQ will assess *E. coli* data for the recreation season provided there are at least 5 collection events during the season (May – October). Exceedances of the geometric mean criterion will result in the site being classified either as impaired (minimum of 10 collection events in a recreation season) or as insufficient data (sample size is more than five but less than 10).

- Scenario C: Seasonal geometric mean assessment.

For each AU with ≥10 collection events in any recreation season, the geometric mean of all samples should not exceed 126 MPN/100 mL for 2A waters or 206 MPN/100 mL for 1C/2B waters throughout the most recent six years recreation seasons.

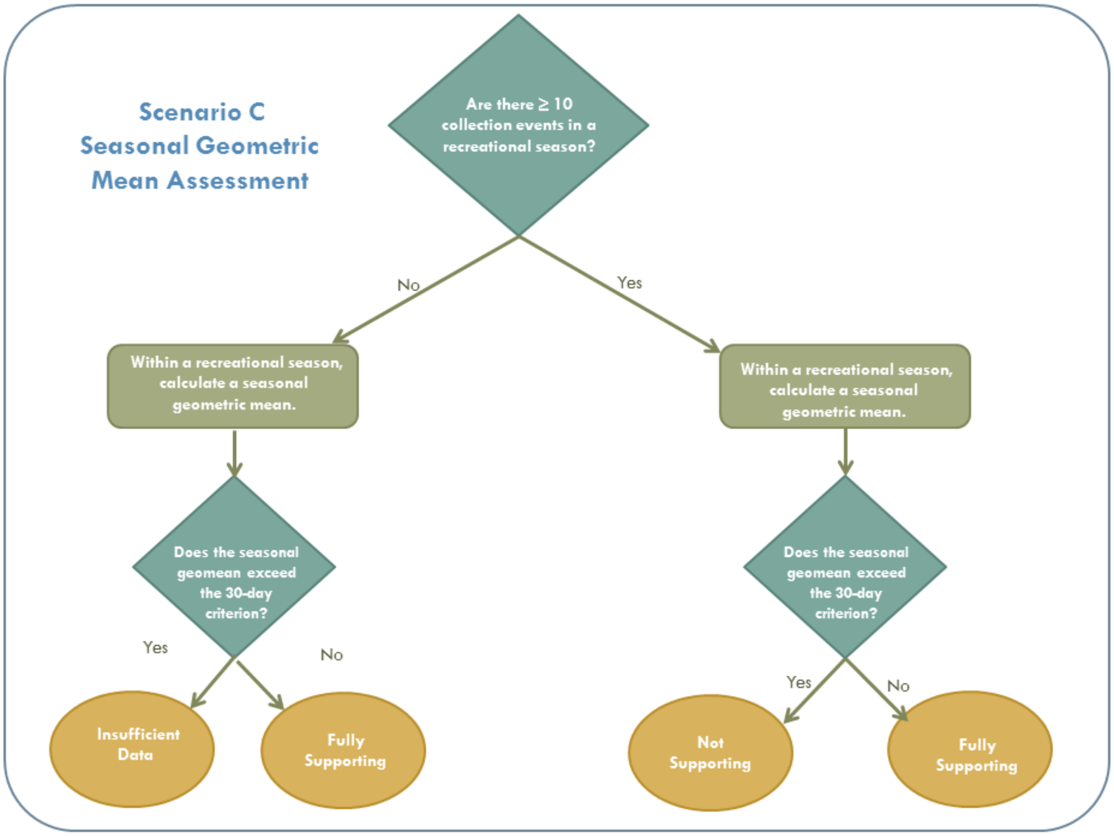


Figure 5: Seasonal geometric mean assessment

AUs with ≤4 samples in any recreation season will not be assessed for support of recreation uses. These sites will be prioritized for future sampling, particularly if limited data suggest a problem exists in the waterbody.

Sample collection and laboratory analysis are performed as prescribed in the approved UDWQ protocols which are consistent with EPS guidelines. All persons conducting sampling or analysis receive annual training by UDWQ personnel. Replicates were collected for most of the North Fork Virgin River *E. coli* collection events. For those results the geometric mean of samples is used to represent a single collection event. Field blanks were also collected on each sampling run as per DWQ monitoring protocol.

Assessment of Recreational and Drinking Water Uses

When determining the use attainment of a monitoring location with assessment results across multiple years, the following rules are applied (in the following order):

Not Supporting (Category 5)

A waterbody is considered to be impaired (not meeting its designated uses) if any of the following conditions exist:

- A lake or reservoir that has two or more posted health advisories or beach closures during any recreation season.
- Any monitoring location where *E. coli* concentrations from 10% or more of the collection events exceed the maximum criterion.
- Any monitoring location where the 30-day geometric mean exceeds the 30-day geometric mean criterion (minimum five collection events with at least 48 hours between collection events).
- Any monitoring location where the recreational season (May–October) geometric mean exceeds the 30-day geometric mean criterion (minimum of 10 collection events).

Insufficient Data or Information Assessment Considerations (Category 3A)

- Sites with four or fewer samples in all seasons evaluated will be listed as not assessed, provided impairment is not suggested by a posted health advisory or beach closure. This applies at lakes and reservoirs only.
- All Category 3A sites will be prioritized for future monitoring, especially if limited data suggest impairment.

Fully Supporting (Category 1 or 2)

- No evidence of impairment by any assessment approach for all recreation seasons over the most recent 6 years. A fully supporting determination can be made with a minimum of five collection events during the recreational season.

2.8 TMDL Endpoints

TMDL endpoints represent water quality targets. For *E. coli*, the reductions specified in the TMDL to meet the 30-day geometric mean water quality standard will ensure no sample will exceed the acute *E. coli* water quality standard based upon the current data set. The endpoints for the North Fork Virgin *E. coli* TMDL are as follows:

1. For recreation seasons with >5 collection events in any recreation season, no more than 10% of samples collected from May 1st through October 30th should exceed 409 MPN/100 mL.
2. For recreation seasons with ≥5 collection events, no 30-day interval geometric means should exceed 126 MPN/100 mL.

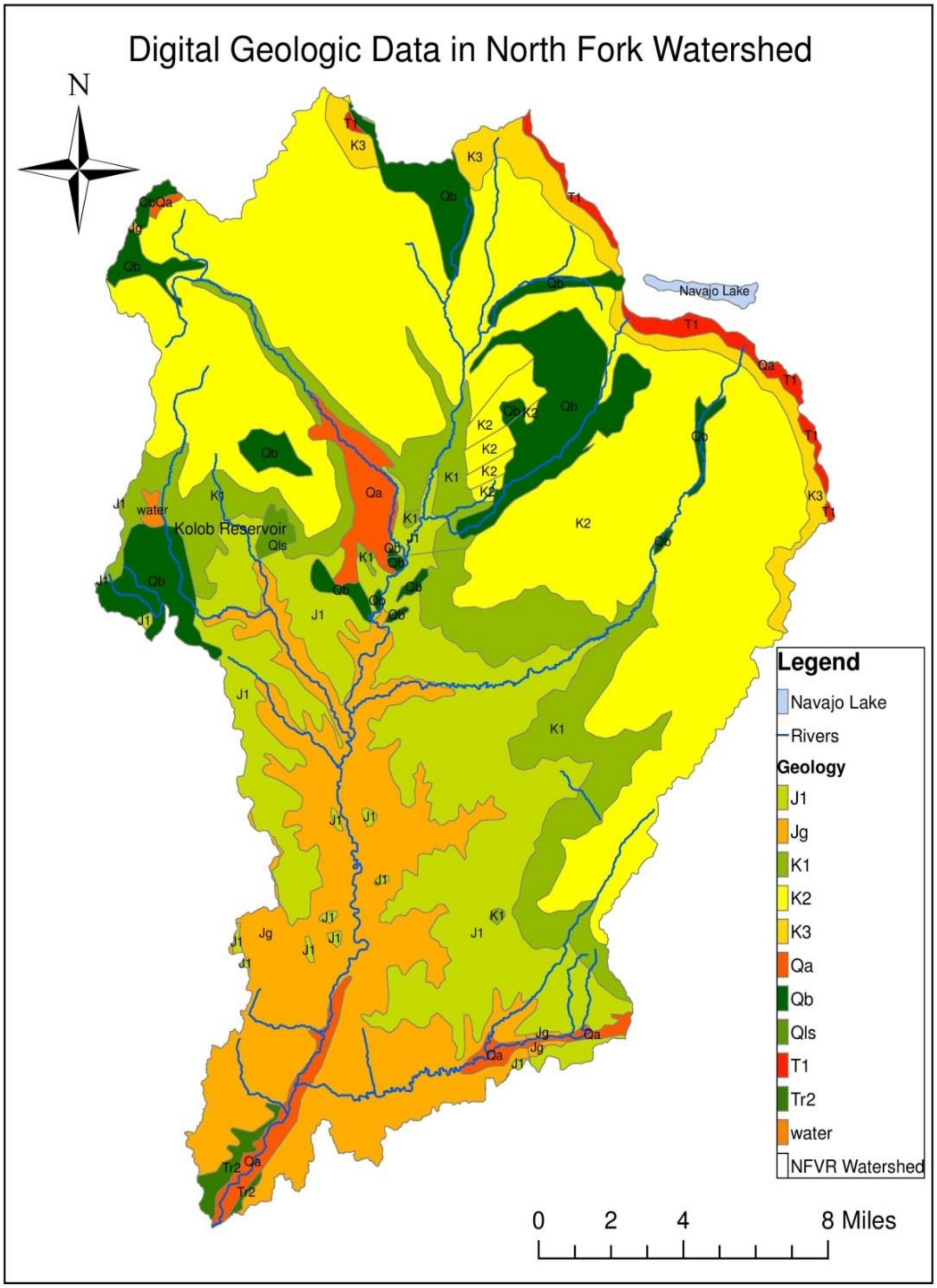
3. For recreation seasons with ≥10 collection events, the geometric mean of all samples should not exceed 126 MPN/100 mL.

3.0 WATERSHED CHARACTERIZATION

3.1 Physical Features

Geology

The Utah Geologic Survey (UGS) has digitized geologic data for the entire State of Utah. This data can be obtained from: http://geology.utah.gov/maps/gis/index.htm. The main geologic formations in the North Fork Watershed are Indianola, Mancos, Frontier, Straight Cliffs, and Iron Springs (K2) which comprise 39% of the formations surveyed, then Summerville, Entrada, Carmel, Arapien, and Twin Creek (J1) at 18%. See Table 4 for the breakdown of the entire survey. Map 3 displays the geologic data visually. The significance for water quality of this geologic setting is that several of these strata are highly erodible and produce abundant sediment in the sand, silt and clay size range. This sediment is mobilized during flood events and carries with it fecal bacteria that have been deposited on the ground or previously settled to the bottom of the stream.



Map 3: Geologic Data in the North Fork Virgin River Watershed

Unit Symbol	Unit Name	Area (mi2)	%
K2	Indianola, Mancos, Frontier, Straight Cliffs, Iron Springs and other Fms	141	39
J1	Summerville, Entrada, Carmel, Arapien, Twin Creek and other Fms	63.9	18
Jg	Glen Canyon Group Navajo, Kayenta, Wingate, Moenave Fms and Nugget Ss	60.1	17
K1	Dakota, Cedar Mountain, Kelvin and other Fms	39	11
Qb	Volcanic rocks-mostly basalt	28.9	8
K3	Mesaverde Group, Price River, Kaiparowits, Echo Cyn and other Fms	10.2	3
Qa	Surficial alluvium and colluvium	9.9	2
T1	Wasatch, Cotton, Flagstaff, Claron, White Sage and other Fms	3.6	1
Tr2	Chinle, Ankareh Fms	1.5	<1
Qls	Surficial landslide deposits	0.9	<1
Water	Water	0.4	<1
Total		359.4	100%

Table 4. Geologic Formations within the North Fork Virgin River Watershed

General Flow

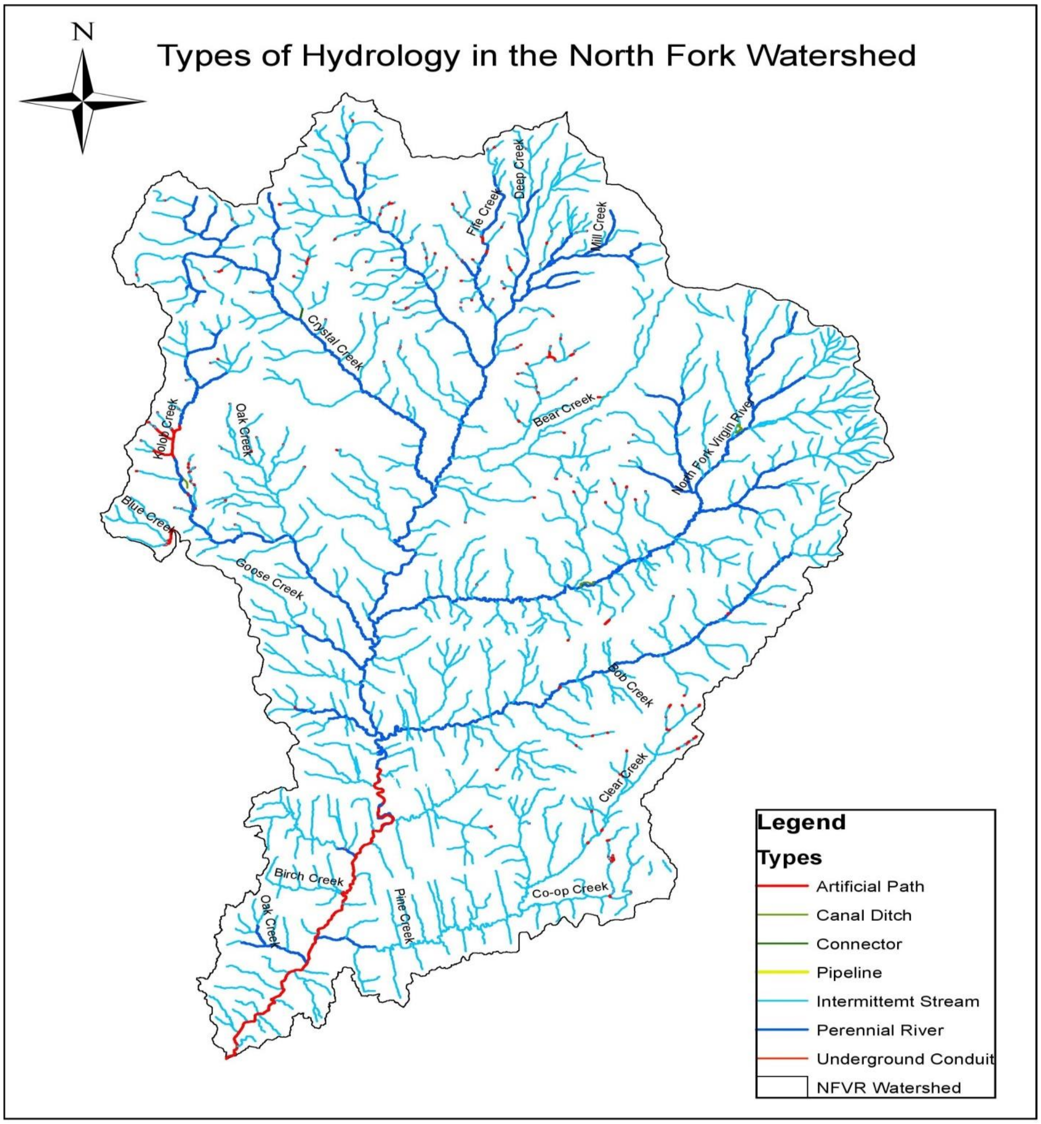
The hydrology of the North Fork Virgin River watershed is dominated by spring runoff from winter snows and rainstorms that occur in late summer and year-round base flow that discharges from many springs. The natural hydrology of the watershed remains relatively intact with a few exceptions. The main alterations have taken place in Zion National Park where in the 1930's the Civilian Conservations Corps built revetments along 2 miles of river in order to protect park buildings and land adjacent to the river. Since then many of the towns downstream of the park have also built stream stabilization structures to protect their infrastructure during the high water events that the area is susceptible to. Table 5 shows a summary of stream types in the North Fork watershed. Lengths are estimated from GIS data.

Although Navajo Lake is outside the surficial flow boundary of the watershed, it is noted in this study because of its contribution to the headwaters of the North Fork. The lake originally formed when pre-historic lava flows cut off the uppermost part of the natural surface drainage of Duck Creek, a headwater tributary of the Sevier River. Water discharges from this lake into sinkholes in the eastern end of the valley that feed a karst groundwater system with water flowing both to Duck Creek in the Sevier River Drainage and the North Fork Virgin River. In the 1930s a dike was built to raise the water level and maintain it approximately 13-16 feet deep to increase water storage and control releases of water during the irrigation season.

Stream Type	Stream Length (mi)	Percent (%)
Intermittent Stream/River	630.5	77
Perennial Stream/River	153.7	18
Artificial Path	23.5	3
Canal	1.7	< 1
Pipeline (Aqueduct)	12	1
Connector	.30	< 1
Total	821.7	100

Table 5: Summary of Stream Types in North Fork Virgin River Watershed

Floods are a common feature in the North Fork. The abundance of steep land and barren rock outcrop contributes to the rapid runoff of heavy rain and sends flood torrents down the steep narrow canyons. For the watershed as a whole, the largest floods are caused by winter rain-on-snow events lasting several days in duration. For the smaller sub-watersheds the largest floods are the result of intense summer thunderstorms. There are also spring snowmelt floods of lower magnitude and lasting several weeks following particularly snowy winters. In a natural system such as this, where the river transports an enormous amount of suspended sediment, some exceedences of the acute standard can be expected during flood events.



Map 4: Stream Types in the North Fork Virgin River Watershed

Water Supply and Uses

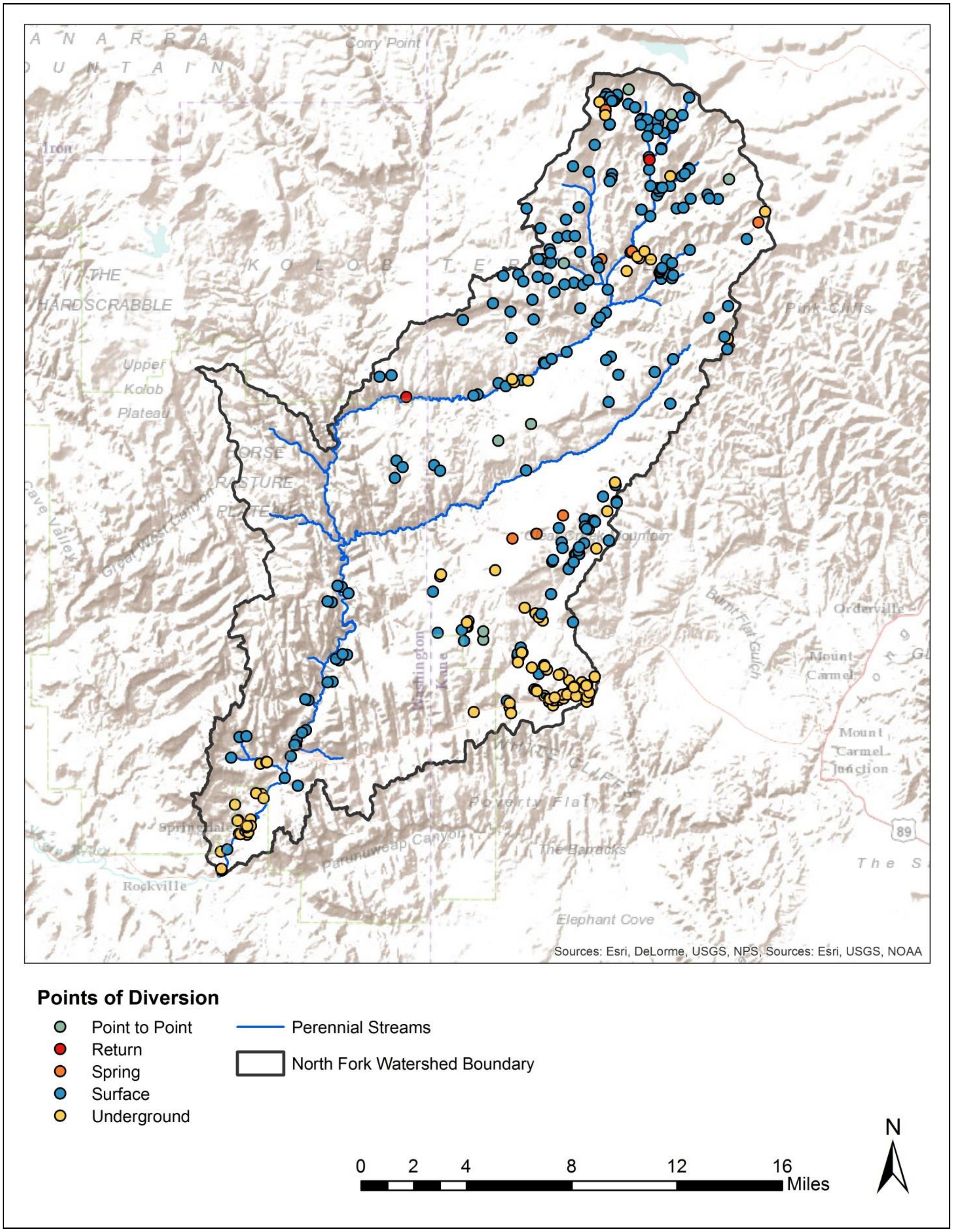
Water Supply and Uses

Data from the Utah Division of Water Rights indicate that 605 points of diversion exist in the North Fork Virgin watershed and total 33,847 acre-feet of water (Table 6). The largest of these diversions occur at the downstream end of Zion Canyon. Diversions are categorized by type that include surface, point to point, return, spring, and underground. Point to point diversions are not developed but reference a stream segment from which livestock may drink.
Primary water right holders in the watershed are the National Park Service, Washington County Water Conservancy District, and St. George and Washington

Canal Company. Other water right holders include private landowners, ditch companies, irrigation companies, and municipalities.

Type of Diversion	Number	Amount (acre-feet)
Surface	380	31,458
Point to Point	10	3
Return	2	1
Spring	13	12
Underground	200	2,373
Total	605	33,847

Table 6: Points of diversion in the North Fork Virgin River Watershed.



Map 5: Points of diversion in the North Fork Virgin River Watershed.

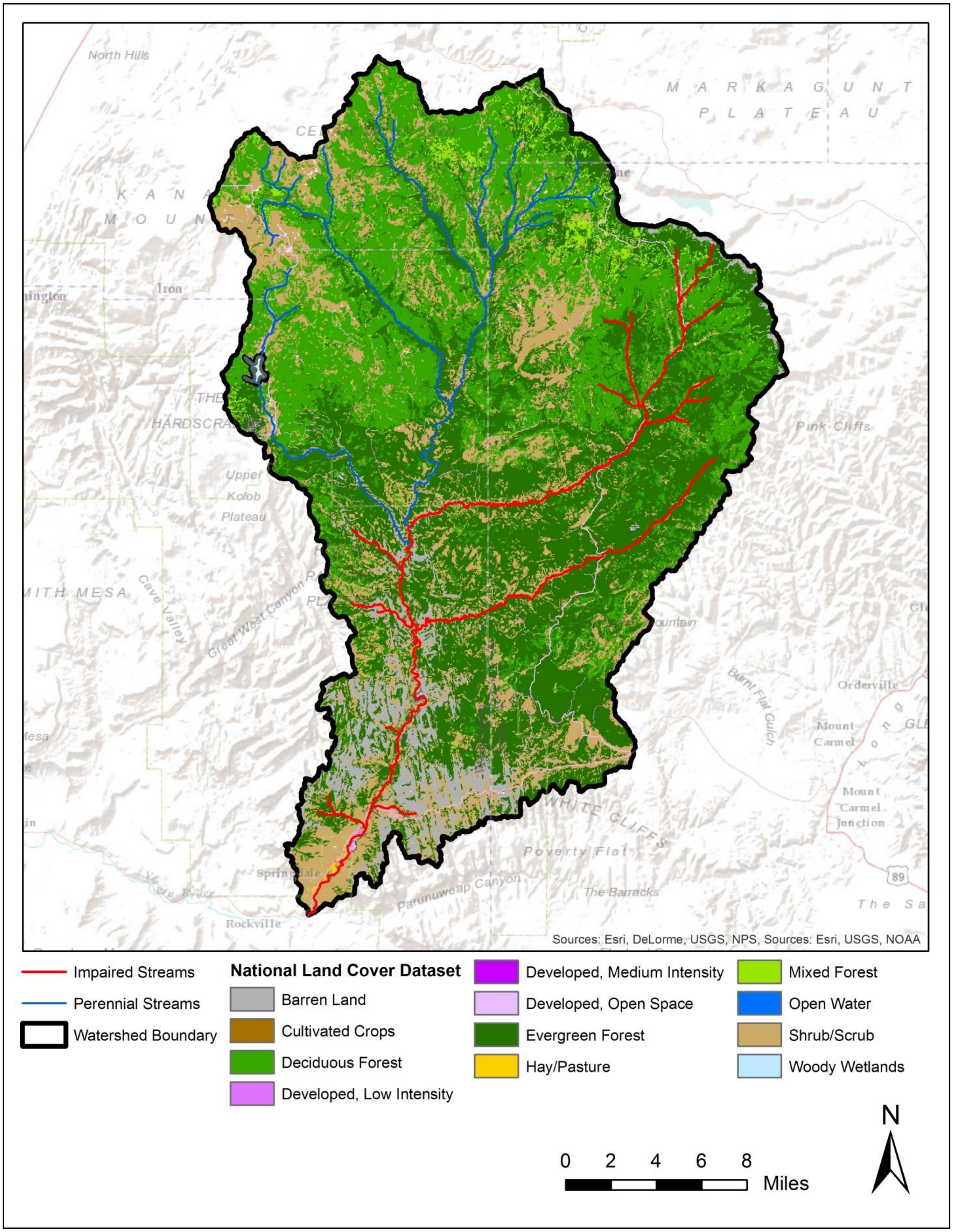
Land Cover

Land cover is an important parameter to consider when determining *E. coli* loads to receiving waterbodies. Land cover data for the North Fork Virgin Watershed were obtained from the 2011 National Land Cover Database. These data are summarized in Table 7 and are shown on Map 6.

Results indicate that land cover is dominated by evergreen forests (41%), deciduous forests (29%), and shrub/scrub (21%). Other land cover classes including barren land, mixed forest, and developed lands are less than 5%.

Table 7: Land Cover in the North Fork Virgin Watershed

	Acres	Percentage Acres
Evergreen Forest	94,226	41%
Deciduous Forest	65,420	29%
Shrub/Scrub	47,741	21%
Barren Land	12,095	5%
Mixed Forest	5,528	2%
Developed, Open Space	2,728	1%
Cultivated Crops	11	< 1%
Developed, Low Intensity	409	< 1%
Developed, Medium Intensity	27	< 1%
Hay/Pasture	140	< 1%
Open Water	257	< 1%
Woody Wetlands	91	< 1%
Total	**228,673**	**100%**



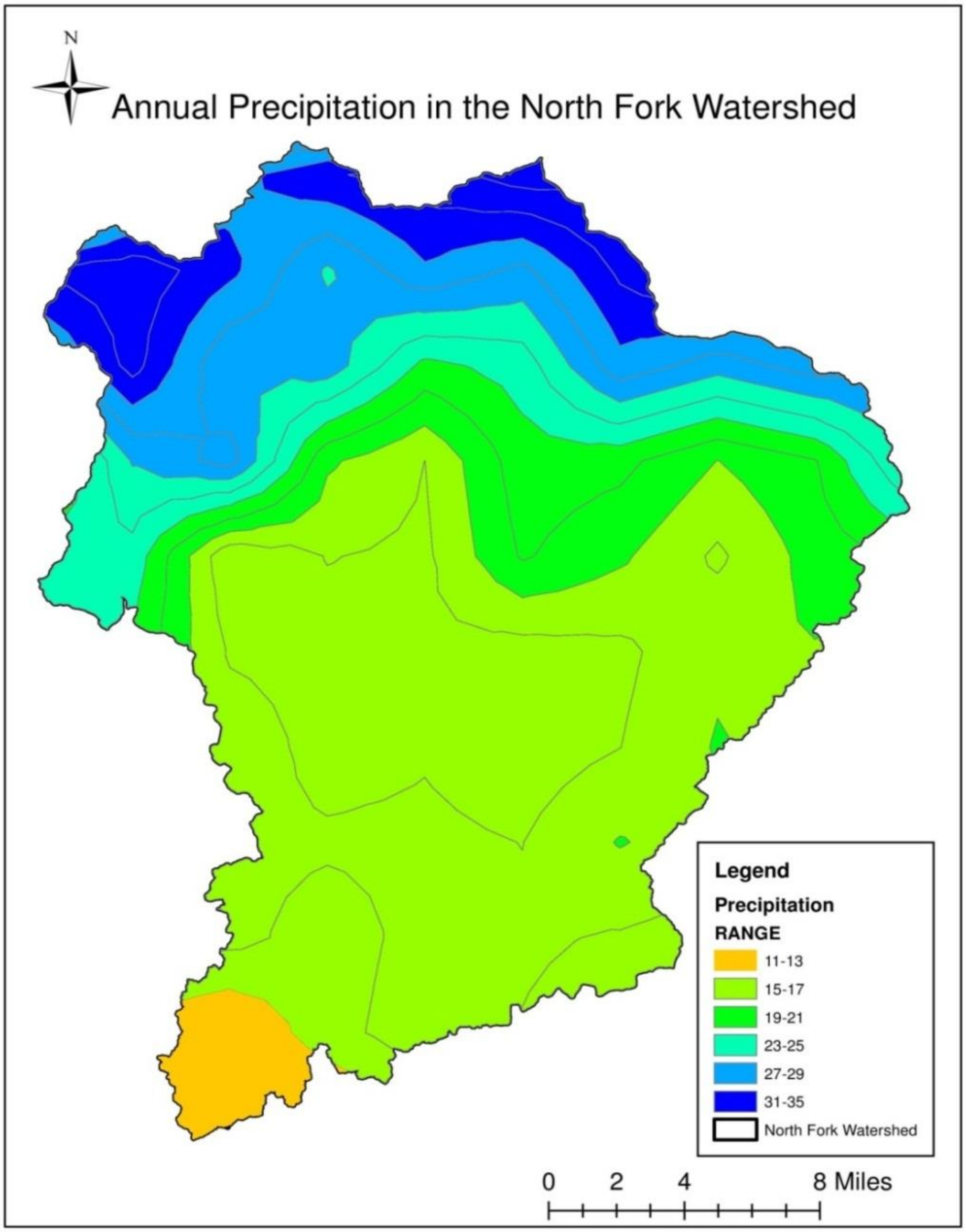
Map 6: Land cover in the North Fork Virgin Watershed.

Ground Water Resources

Water-related resources in the North Fork Virgin River Watershed depend heavily on ground-water discharge to maintain flow in streams. Navajo Sandstone is one of the more important consolidated aquifers in the watershed due to the fact that wherever the formation is found water is present. In 2005 Zion National Park conducted a study with the purpose of quantifying ground-water discharge from the Navajo Sandstone to the East and North Forks. Ground-water discharge from the Navajo Sandstone to the streamflow of the North Fork likely ranges from 24 to 55 cubic feet per second (CFS). That amount varies year-to-year depending on the amount of groundwater recharge from the melting of winter snows. This estimated range comprised as much as 100 percent of the minimum CFS and 85 percent of the median streamflow (65 CFS) of the North Fork (Christensen). Groundwater discharges upstream of the Navajo Sandstone maintain smaller perennial stream flows in the upper part of the watershed.

Climate and Precipitation

Annual temperatures and precipitation vary greatly within the watershed and are mainly tied to changes in elevation. Annual average temperatures range from 35° F at the highest elevation headwaters to 61° at the confluence with the East Fork with an overall average of 46° F. Precipitation, like the majority of Utah, is dictated by two distinct seasons. Pacific Northwest frontal systems bring winter and spring precipitation in the form of snow at higher elevations and rain at lower elevations and late summer monsoonal rains bring moisture to the entire region. Average annual precipitation ranges from 11-15 inches near Springdale and the lower portions of the watershed to approximately 35 inches in the mountains near the headwaters of the North Fork.



Map 4: Annual Precipitation (inches) in the North Fork Virgin River Watershed

3.2 Biological Features

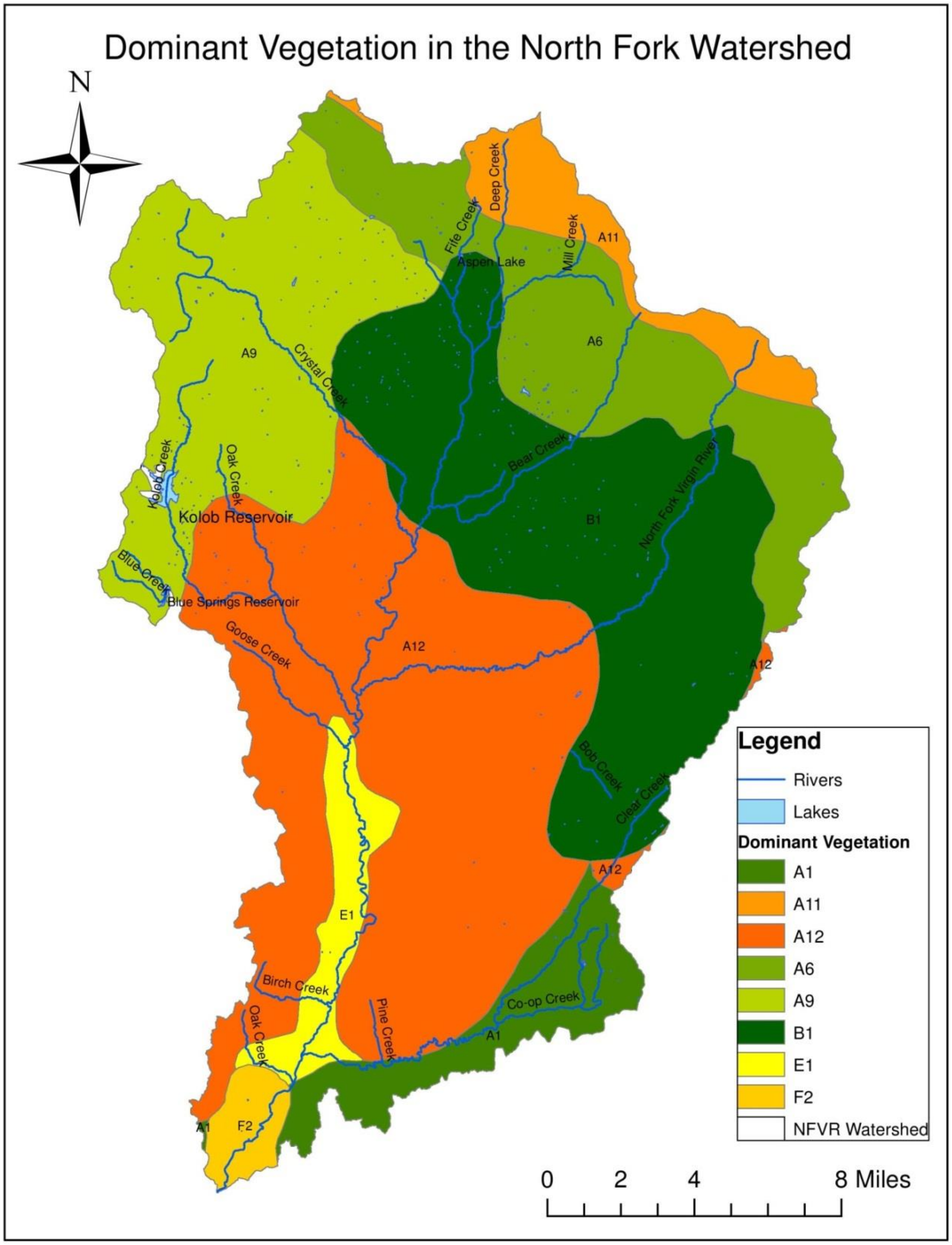
Vegetation

Vegetation data was gathered from the Gap Analysis Project (GAP) completed for the State of Utah. GAP classifications for the North Fork watershed are summarized in Table 7 and displayed in Map 5. Ponderosa Pine accounted for

33% of total watershed land cover, Oak 24%, and Alpine Fir at 16%. It is important to note that at the scale of the GAP analysis, the boundaries of vegetation types that form narrow bands along streams, specifically Fremont cottonwood and cultivated lands, are very approximate and generally depicted as larger than actual.

Code	Vegetation Type	Area (mi^2)	Percent of Watershed Cover
A12	Ponderosa Pine	117	33
B1	Oak	87	24
A9	Alpine Fir	58	16
A6	Aspen	46	13
A1	Utah Juniper	19	5
A11	Engelmann Spruce	15	4
E1	Fremont Cottonwood	12	3
F2	Cultivated Land	5	1
G1	Water	.4	<1
Total		359.4	100%

Table 7: Dominant Vegetation Types in the North Fork Virgin River Watershed



Map 5: Dominant Vegetation in the North Fork Virgin River Watershed

Fisheries and Wildlife

The great diversity in topography, climate, hydrology, and land cover results in a diverse ecosystem with a large variety of wildlife. Zion National Park reports that it is home to 78 species of mammals, 291 species of birds, 44 species of reptiles and amphibians, and 8 species of fish. The park is centrally located in the North Fork watershed so those numbers should be fairly representative of wildlife throughout the entire watershed with the addition of a few more high-elevation species. Game species include mule deer, Rocky Mountain elk, and wild turkey. Additionally, big horn sheep were recently reintroduced to the area. Other mammals include mountain lion, bobcat, coyote, fox, and various bat and rodent species. Many reptiles can be found in the area including plateau lizards, gopher snakes, and the western rattlesnake.

A large variety of birds can be found in the area from large falcons and condors to hummingbirds. Waterfowl are also common to the area; ducks, geese, and herons use the streams and lakes in the watershed for habitat and nesting. In addition, many species of passerines, raptors, and vultures can be found throughout the watershed, some of which have made notable recoveries such as the peregrine falcon and California condor.

The North Fork Virgin River supports 4 species of native fish populations. The species include the virgin spinedace (*Lepidomeda mollispinis mollispinis*), desert sucker (*Catostomus clarkii*), speckled dace (*Rhinichthys osculus*), and flannelmouth sucker (*Catostomus latipinnis*). These fish are well adapted to the floods and periods of low flow which occur frequently in the watershed. The majority of these fish are found from the confluence of the East and North Fork to the bottom end of the Narrows where the number of fish drops sharply due less suitable habitat within the slot canyon.

Exotic rainbow, cutthroat, brook and brown trout are found in the North Fork above the Narrows, in Kolob Reservoir to the northeast, and in small numbers below the Narrows. These fish were introduced to the North Fork in the past to provide a sport fishery to the area. Stocking of this area was ceased long ago in recognition of the damage it could have on the native fish populations, and with the exception of Kolob Reservoir, the poor quality of the available habitat. Kolob Reservoir continues to be stocked with rainbow and cutthroat trout to supplement the sport fishery.

Protected Species

It is important to identify threatened and endangered species and species of concern when planning water quality improvement efforts. Such efforts may enhance habitat for these species and present opportunities for sharing costs of water quality improvement efforts with other agencies whose primary focus is wildlife management. The species listed below in Table 8 represent the fauna which are currently listed on the Utah Sensitive Species List and reside in the North Fork Virgin River watershed.

By rule, wildlife species that are federally listed, candidates for federal listing, or for which a conservation agreement is in place automatically qualify for the Utah Sensitive Species List. The additional species on the Utah Sensitive Species List, "wildlife species of concern," are those species for which there is credible scientific evidence to substantiate a threat to continued population viability.

Type	Common Name	Scientific Name	Status[1]
Amphibian	Arizona Toad	*Bufo microscaphus*	SPC
Bird	Bald Eagle	*Haliaeetus leucocephalus*	SPC
	California Condor	*Gymnogyps californianus*	S-ESA (Experimental, Non-essential population in Utah)
	Lewis's Woodpecker	*Melanerpes lewis*	SPC
	Northern Goshawk	*Accipiter gentilis*	CS
	Southwestern Willow Flycatcher	*Empidonax traillii extimus*	S-ESA
	Spotted Owl	*Strix occidentalis*	S-ESA
	Three-Toed Woodpecker	*Picoides tridactylus*	SPC
	Yellow-Billed Cuckoo	*Coccyzus amerianus*	S-ESA
	American White Pelican	*Pelecanus erythrorhynchos*	SPC
	Ferruginous Hawk	*Buteo regalis*	SPC
	Black Swift	*Cypseloides niger*	SPC
Mammal	Fringed Myotis	*Myotis thysanodes*	SPC
	Spotted Bat	*Euderm maculatum*	SPC
	Townsends Big-Eared Bat	*Corynorhinus townsendii*	SPC
	American Pika	*Ochotona princeps*	SPC
Mammal	Allens Big-Eared Bat	*Idionycteris phyllotis*	SPC
	Big Free-Tailed Bat	*Nyctinomops macrotis*	SPC

	Western Red Bat	*Lasiurus blossevillii*	SPC
Mollusk	Wet-Rock Physa	*Physella zionis*	SPC
Reptile	Desert Tortoise	*Gopherus agassizii*	S-ESA
	Zebra-Tailed Lizard	*Callisaurus draconoiodes*	SPC
	Gila Monster	*Heloderma suspectum*	SPC
	Western Banded Gecko	*Coleonyx variegatus*	SPC
Fish	Virgin Spinedace	Lepidomeda mollispinis	CS
	Flannelmouth Sucker	Catostomus latipinnis	CS
[1] SPC: Wildlife species of concern. CS: Conservation species receiving special management under a Conservation Agreement to preclude Federal listing. S-ESA: Federally-listed or candidate species under the ESA.			

Table 8: Protected Species in the North Fork Watershed Data summarized from Utah's State Listed Species. (DWR 2011)

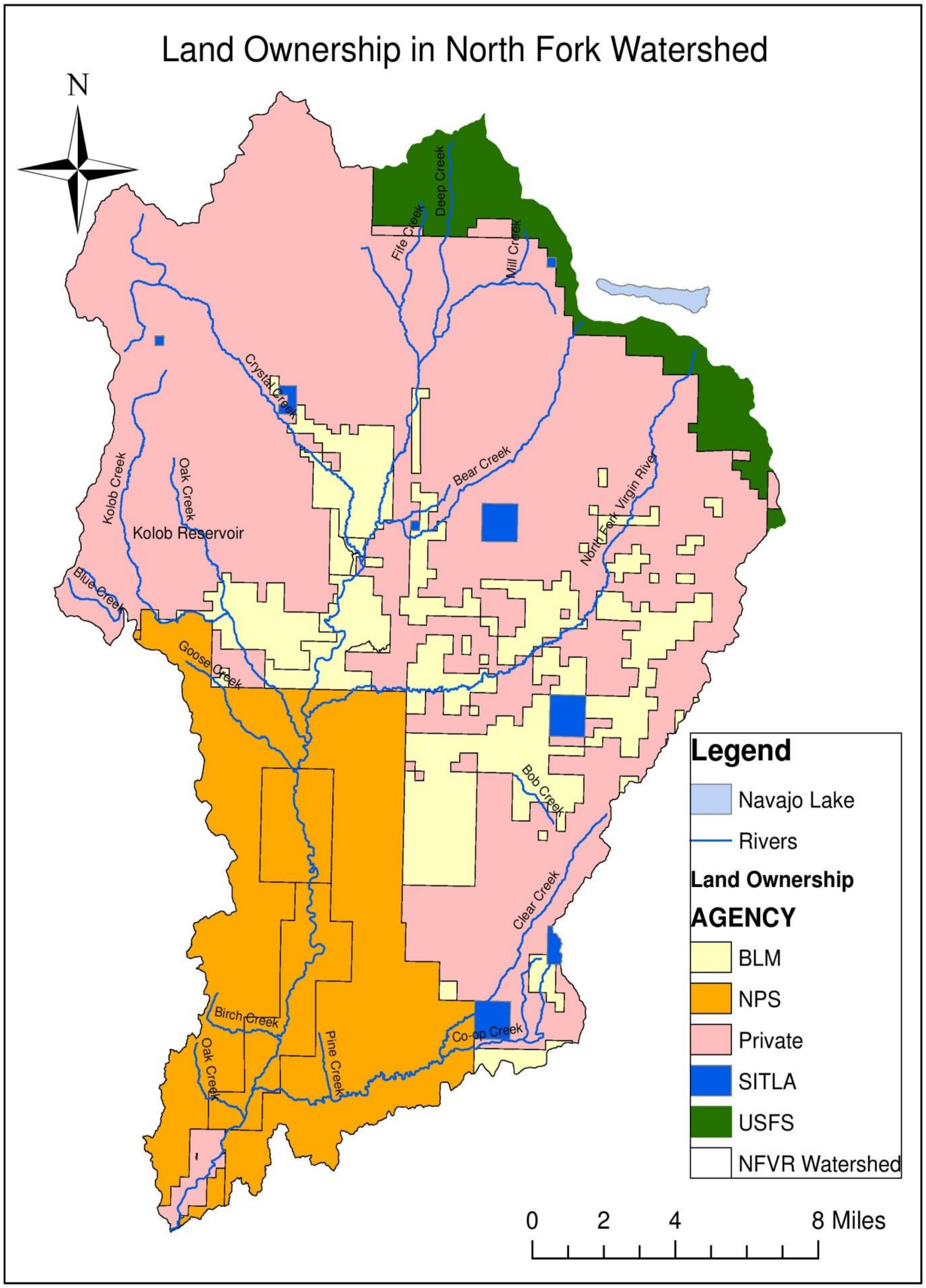
3.3 Population and Land Use

Land Ownership

Land ownership information was digitized for the Utah GAP analysis and is available for the entire state of Utah. This dataset describes general land management units as well as enclaves of land ownership within each management unit. Various federal, state, and private entities are responsible for managing land throughout the North Fork watershed. Private landowners manage the majority of the land in this watershed (57%). This land sits mainly at the north end of the watershed and is the headwaters of many tributaries of the North Fork Virgin River. Zion National Park manages the second largest piece (22%) which is composed of most of the land in the southwestern end of the watershed.

Landowner	**Area (acre)**	**Area (mi^2)**	**Percent (%)**
Private	131,066	204.8	57
National Park Service	54,456	80.4	22
BLM	33,664	52.6	15
Forest Service	11,648	18.2	5
School and Institutional Trust Lands Administration (SITLA)	2,496	3.9	1

Table 9: Land Ownership in the North Fork Watershed



Map 6: Land Ownership in the North Fork Virgin River Watershed

Access

While paved highways bring millions of people a year to visit Springdale and Zion Canyon, the upper parts of the watershed are accessible only by county-maintained and private dirt roads. The North Fork Road is the primary access route and is unpaved for a distance of 16 miles when traveling from the south and 18 miles when traveling from the North. It is closed by snow through the winter and mud through the spring so there are no year-long residents. Additionally, it traverses soils rich in clays and can become impassible in summer following only moderate rainfall. The significance for the mitigation of water quality problems is that managing a livestock operation and irrigation system is difficult when every site visit requires an hour or more of travel and road conditions could deteriorate and make the operation inaccessible at any time. Actions such as closing a ditch during a flood so it doesn't fill with sediment are typically not possible.

4.0 WATER QUALITY DATA

4.1. Previous Bacteria Water Quality Study

During the summer use seasons of 2000 and 2001, Zion National Park undertook a reconnaissance of fecal bacteria levels in many of the waters flowing through the park. The majority of the samples (201) were from six sites along the North Fork Virgin River.

Among the six North Fork sites, only the North Fork Virgin River at the Narrows Trailhead had a geometric mean that exceeded the previous 200 FC/100 ml standard with consistency. Sixty-one percent of the 23 samples collected there had fecal coliform levels above the standard. That site also frequently had high levels of fecal bacteria during clear base-flow conditions; a pattern indicating a source of significant bacteria loading outside of the natural pattern during dry weather.

4.2 Flow Data

There is one stream flow gage on the North Fork Virgin River (USGS #09405500: North Fork Virgin River near Springdale, UT) located in Zion National Park approximately two miles upstream of the western Park boundary. It is operated and maintained by the US Geological Survey and has a period of record of stream flow at that location from 1923-present.

Flow measurements are critical for calculating bacteria loading to the river. Monitoring staff have consistently measured stream flow at one location in the upper watershed, North Fork Virgin River at End of Road. That monitoring location has been selected for the upper North Fork Virgin River-2 Assessment Unit TMDL calculations because it showed the highest degree of impairment. Subsequent data collection at this location should adequately indicate the impairment status of the upper AU.

The Temple of Sinawava monitoring location was used for the TMDL data analysis for the lower North Fork Virgin River-1 Assessment Unit. Flows were estimated for that location using the USGS gage approximately 6 miles downstream. There are a few small tributaries joining between the site and the gage including Birch Creek, Echo Canyon, Heaps Canyon, Pine Creek, and a few springs. However the diversions for the Park and the adjacent town of Springdale total 4-7 CFS depending on whether everyone is taking their full allotment. For flow estimates we made the assumption that gains and losses most likely equal out.

It is possible to estimate flows in the upper watershed using a correlation value based off flow data from the USGS Springdale gage. For the few instances when flow could not be measured it was estimated using simple linear regression based off flows at the Springdale gage using a correlation value of 0.215. That correlation value was calculated by comparing flow measurement in the upper watershed at the End of the Road monitoring location to the gage flow. Figure 10 shows monthly mean flow at the USGS gage in Springdale from 1989-2016 and corresponding estimates of mean monthly flow for the North Fork in the upper watershed at the End of the Road monitoring location.

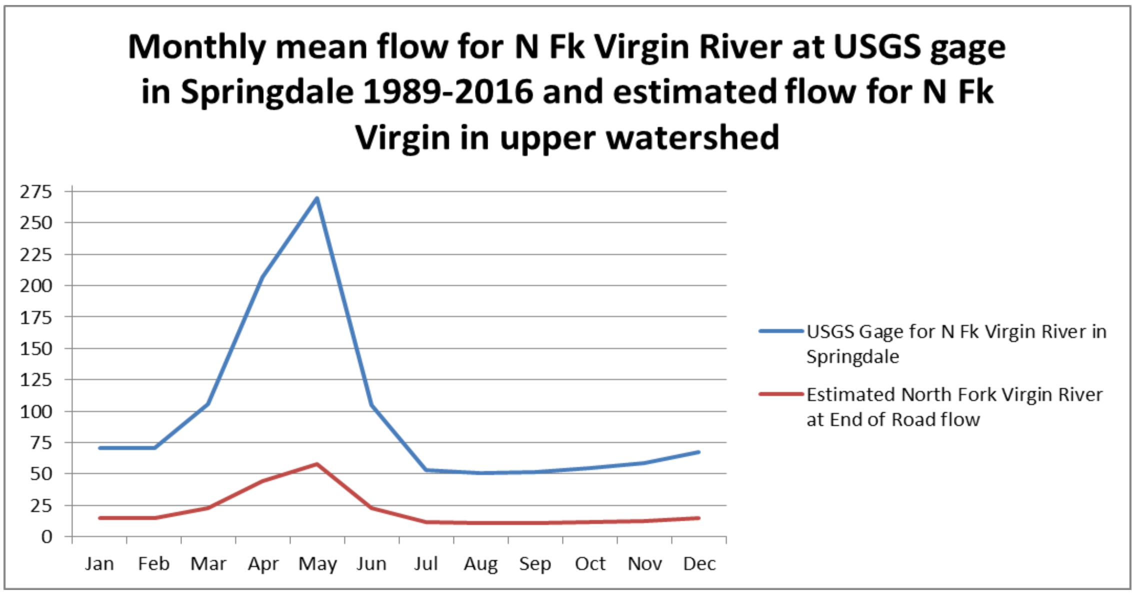


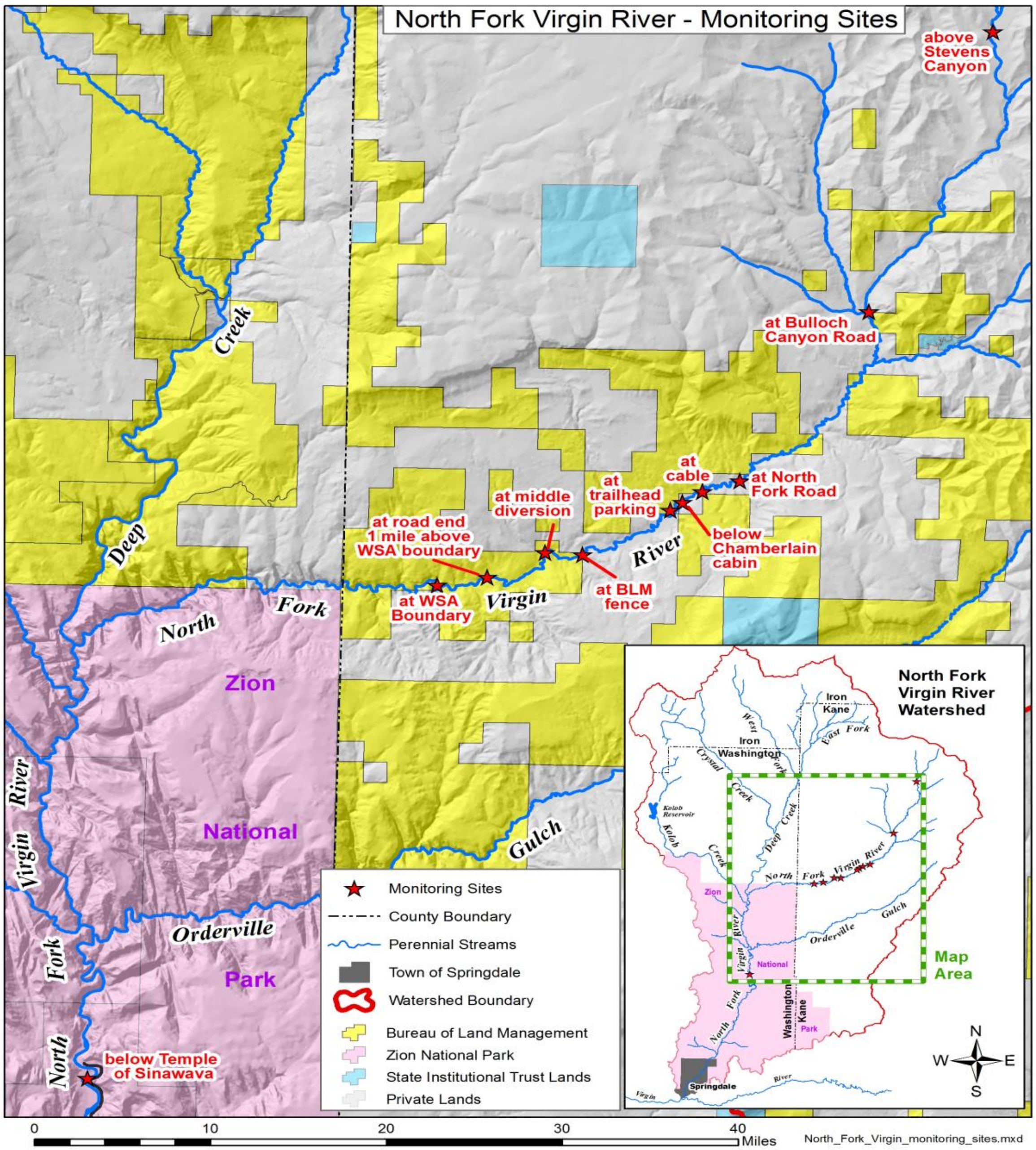
Figure 10: Monthly mean flow for North Fork Virgin River in Springdale and estimated flow for North Fork Virgin River at End of Road

4.3 Monitoring Results

The North Fork Virgin River has been sampled intensively for *E. coli* since 2009 when exceedances of the Utah standard were first measured. Sampling has been a joint effort between the Utah Division of Water Quality, Zion National Park, and the Kanab Bureau of Land Management.

As Map 7 illustrates, many sites have been established for monitoring *E. coli* in the upper portion of the watershed. The North Fork Virgin River at the End of the Road site is used for the TMDL data analysis for the upper Assessment Unit. This sampling location is at a natural transition between differing land uses with irrigated lands and road access upstream and undeveloped lands and wilderness downstream. The location is downstream of the area in which consistent exceedances have been measured, and downstream of proposed best management practices which will address the impairment.

The Temple of Sinawava monitoring location is the site used for data analysis for the lower Assessment Unit. It is the only site in that Assessment Unit with consistent *E. coli* data. It is also at a transition between lands with road access below, and foot access upstream.



Map 7: North Fork Virgin River monitoring locations

Figure 11: North Fork Virgin River at End of Road.

Figure 12: North Fork Virgin River at Temple of Sinawava.

The following table summarizes all sampling locations within the North Fork Virgin River watershed listed from upstream to downstream. It includes the years sampled and the corresponding *E. coli* recreation season geometric means for those years. The number of samples collected each year is in parentheses. Values highlighted in red show exceedances of the chronic geometric mean standard of 126 MPN/100ml.

Site ID	Site Description (upstream to downstream)	Recreation Season Geometric Means (n) May-October							
		2010	2011	2012	2013	2014	2015	2016	2017
4951253	N Fk Virgin River above Stevens Canyon at Road Crossing	24(21)	-	-	-	-	173(3)	19(9)	29(7)
4951256	N Fk Virgin River at Bulloch Canyon Road	28(25)	-	-	-	-	102(7)	28(10)	15(6)
4951260	N Fk Virgin River at North Fork Road Bridge	23(20)	21(15)	50(10)	24(17)	48(14)	107(16)	28(12)	15(12)
4951279	N Fk Virgin River at Cable	-	-	36(3)	39(16)	100(4)	326(9)	-	-
4951277	N Fk Virgin River below Chamberlain Cabin	-	-	39(3)	51(6)	91(3)	130(2)	-	-
4951263	N Fk Virgin River at Narrows Trailhead	-	127(12)	171(8)	65(10)	125(14)	161(16)	42(10)	21(12)
4951272	N Fk Virgin River at BLM Boundary Fence	-	-	584(1)	132(17)	163(14)	180(16)	36(11)	21.1(12)
4951264	N Fk Virgin River at Middle Diversion	-	157(11)	280(9)	214(4)	241(3)	428(9)	-	-
4951268	N Fk Virgin River at End of Road	89(20)	179(14)	171(10)	132(12)	120(10)	203(12)	46(7)	47(9)

4951265	N Fk Virgin River at WSA Bndy	434(1)	411(1)	153(7)	118(11)	71(8)	283(11)	51(5)	31(7)
4951199	N Fk Virgin River at Temple of Sinawava	40(22)	58(14)	149(3)	25(15)	46(13)	29(8)	47(10)	29(12)

Table 10: Summary of *E. coli* geometric means for the recreation seasons from 2010-2017.

4.4 Water Quality Analysis

The following charts show *E. coli* concentrations through time compared to the Utah maximum criterion standard and geometric mean standard for all monitoring locations from upstream to downstream. The eight sites and return flows described briefly in this section are used to inform our understanding of the patterns and sources of contamination, while a more detailed TMDL analysis will focus on the End of the Road site and the Temple of Sinawava.

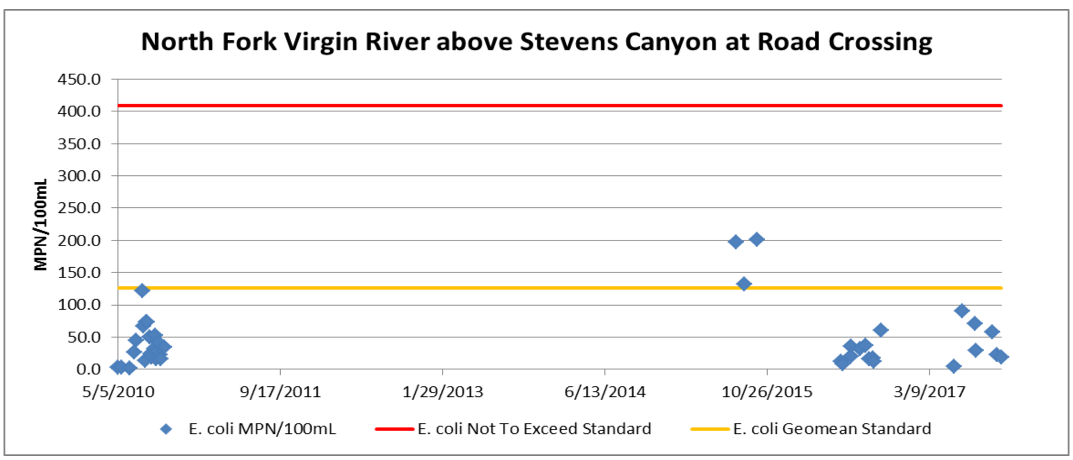


Figure 13: E. coli concentrations measured at North Fork Virgin River above Stevens Canyon at Road Crossing from 2010-2017.

Stevens Canyon is the uppermost monitoring location for this study. It was sampled intensively in 2010. Since all measurements were well below the standard the site was dropped in future years until 2015 when elevated concentrations were measured at downstream locations. The Stevens site was added back to see how far upstream the exceedances could be measured. All 2016 samples were well below 100

MPN/100mL.

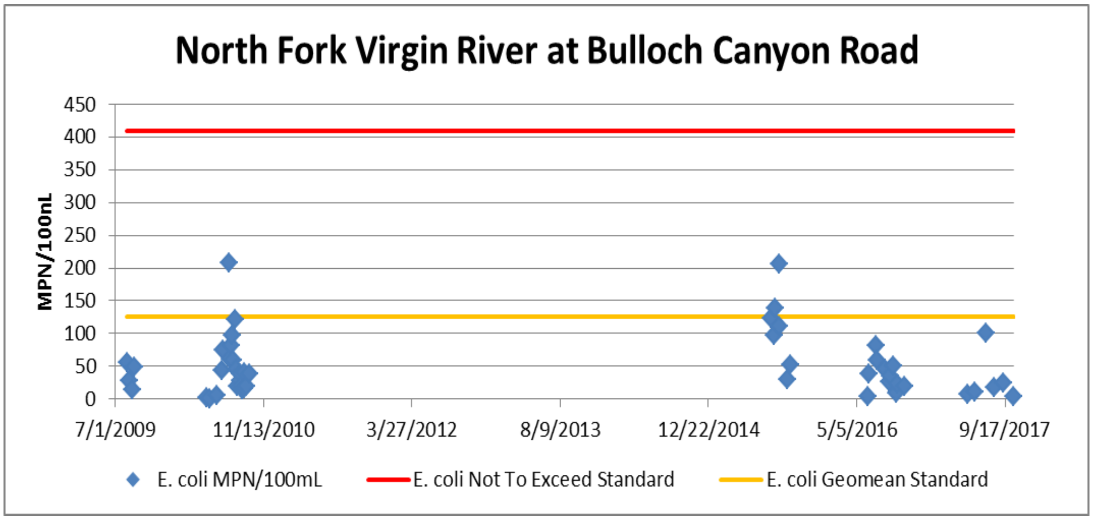


Figure 14: *E. coli* concentrations measured at North Fork Virgin River at Bulloch Canyon Road from 2009-2017.

Similar to the Stevens Canyon site, the Bulloch Canyon site was sampled intensively in 2010 with no exceedances of the maximum criterion measured. It was omitted from the sampling schedule until 2015. All 2016 and 2017 samples were below 100 MPN/100mL.

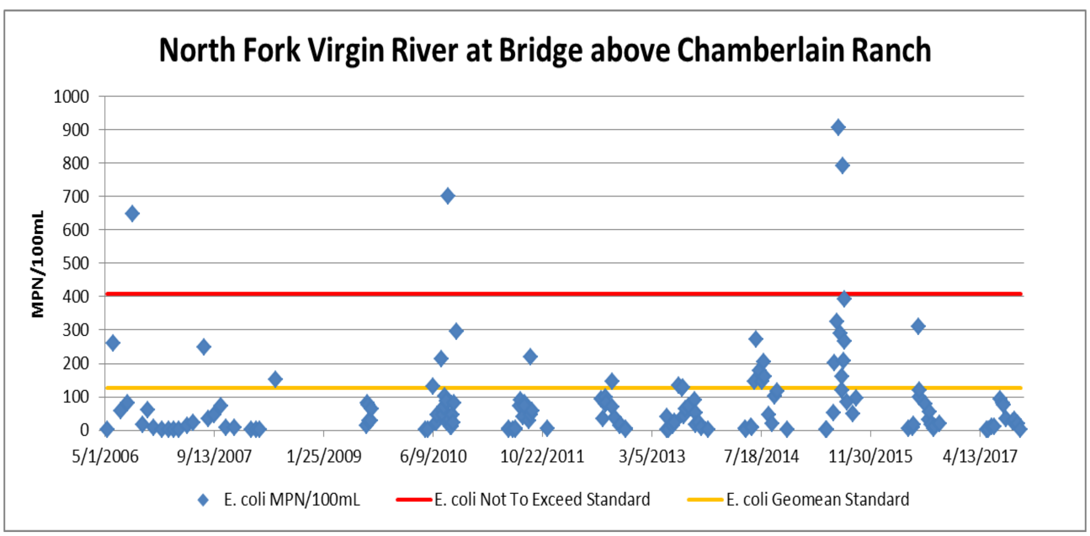


Figure 15: *E. coli* concentrations measured at North Fork Virgin River bridge above Chamberlain Ranch from 2006-2017.

The North Fork Virgin River at Bridge monitoring location has a very robust data set with samples dating back to 2006. Only 4 of 140 samples have exceeded the maximum criterion of 409 MPN/100mL.Immediately downstream is where exceedances were consistently measured.

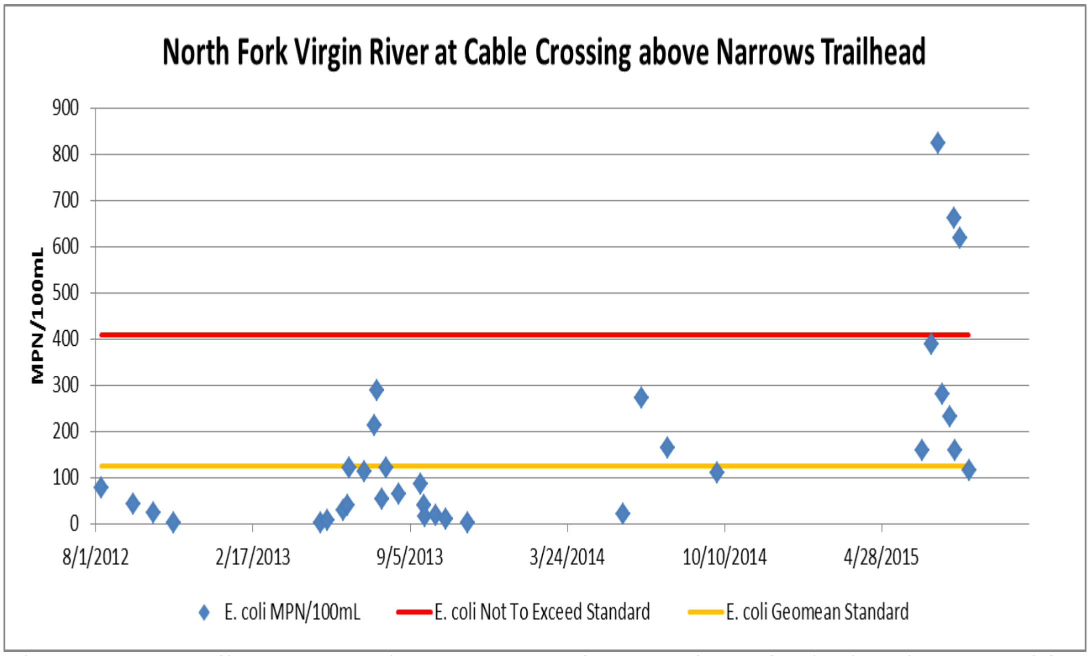


Figure 16: *E. coli* concentrations measured at North Fork Virgin River at cable crossing above Zion Narrows trailhead from 2012-2015.

The Cable Crossing site and the above Narrows Trailhead site which follows are located downstream of the North Fork Bridge site and upstream of the Narrows Trailhead. The Cable Crossing site is at the upstream end of the first irrigated pasture where non irrigation return flows should have reached the river. The next site downstream is below where the first substantial return flows join the river.

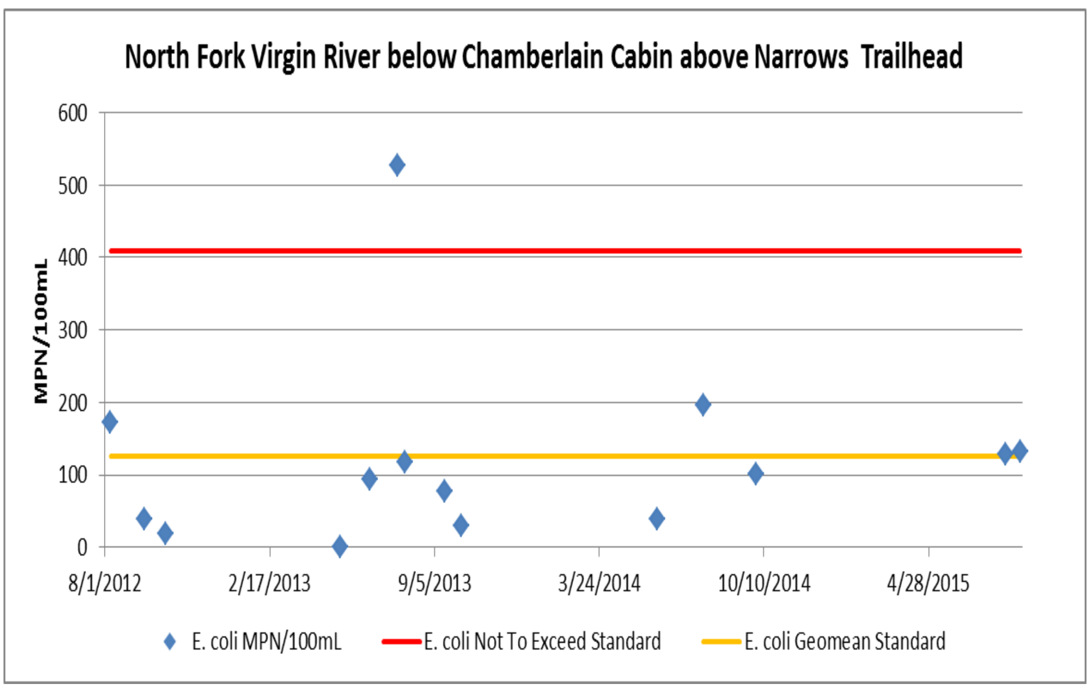


Figure 17: *E. coli* concentrations measured at North Fork Virgin River below Chamberlain Cabin above Narrows Trailhead from 2012-2015.

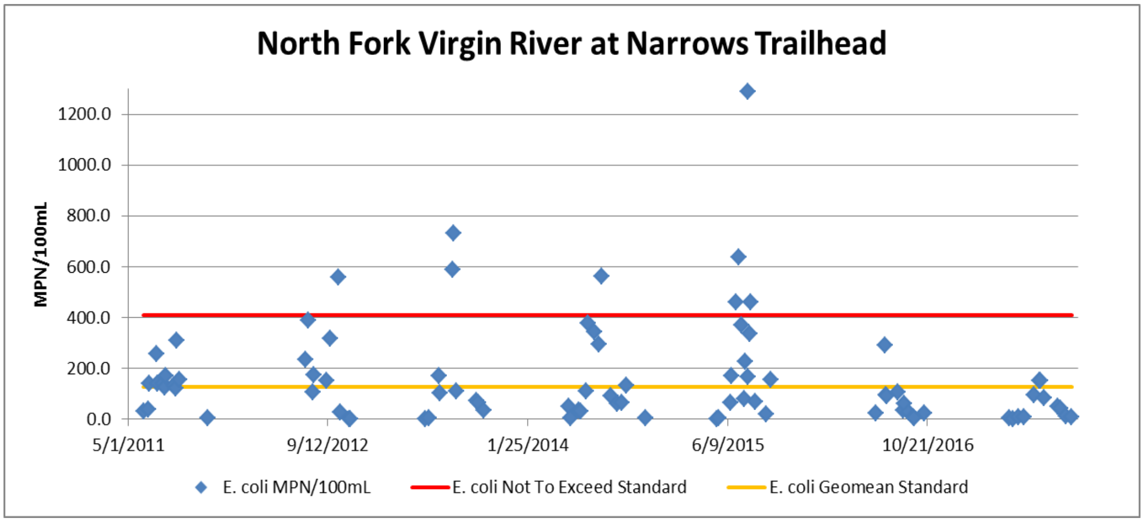


Figure 18: *E. coli* concentrations measured at North Fork Virgin River at Zion Narrows Trailhead from 2011-2017.

The North Fork Virgin River at Zion Narrows Trailhead monitoring location is where hikers begin the Zion Narrows hike. It is located downstream of some flood irrigated pastures and grazing. A pit toilet was installed near the trailhead in 2011 after observations of a persistent problem with human waste disposal at this location.. Note the drop in concentrations in 2016 and 2017, during which no exceedances of the maximum criterion were measured. This drop in *E. coli* concentrations is attributed to a change in management of the property that limited grazing and irrigation for a season to see if that resulted in any improvements in water quality.

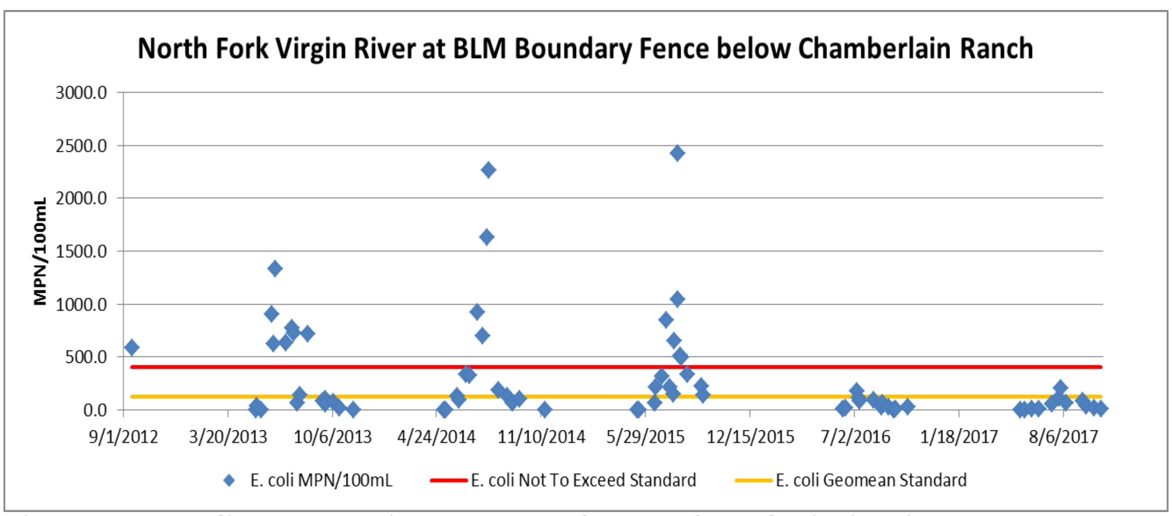


Figure 19: *E. coli* concentrations measured at North Fork Virgin River at BLM Boundary Fence below Chamberlain Ranch from 2012-2017.

The North Fork Virgin River at BLM Boundary Fence monitoring location was added in late 2012 to determine *E. coli* concentrations from private property. It is located at the boundary between private lands upstream and BLM administered pastures downstream. As seen in Figure 19 results for 2013-2015 showed beneficial use impairment at that this location. Note the 2016 and 2017 results that are all below the maximum criterion standard. The observed decrease in *E. coli* levels is most likely due to the changes in grazing and irrigation management on the private pastures upstream.

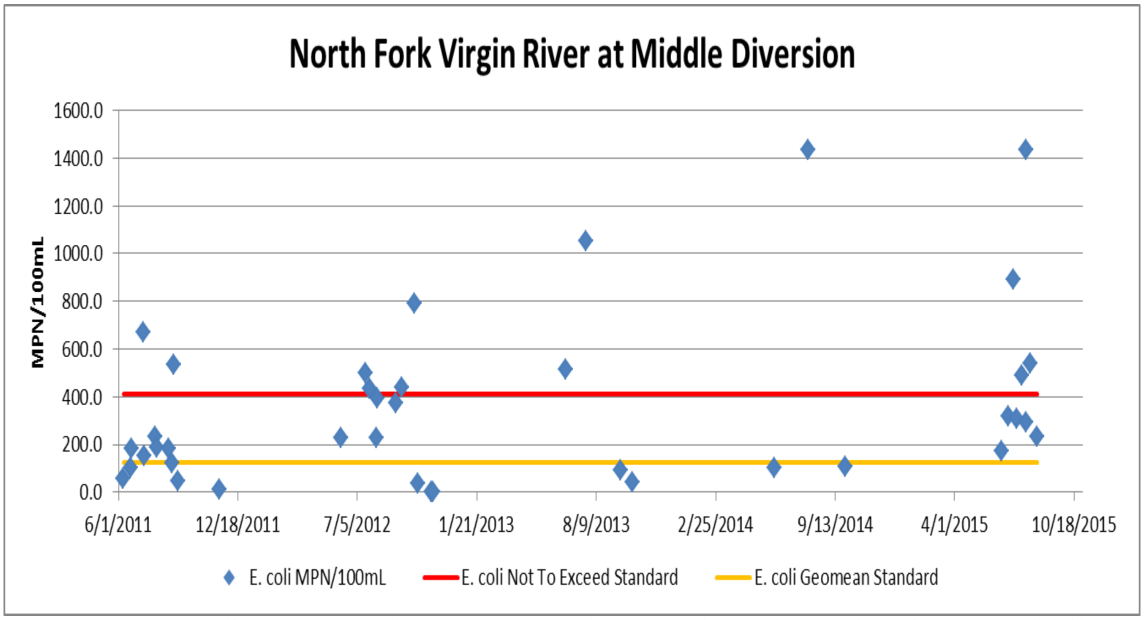


Figure 20: *E. coli* concentrations measured at North Fork Virgin River at Middle Diversion from 2011-2015.

The Middle Diversion monitoring location is on BLM property. Exceedances were measured in 2011-2015. The site was removed from the sampling plan in 2016 because the BLM fence site is a superior location.

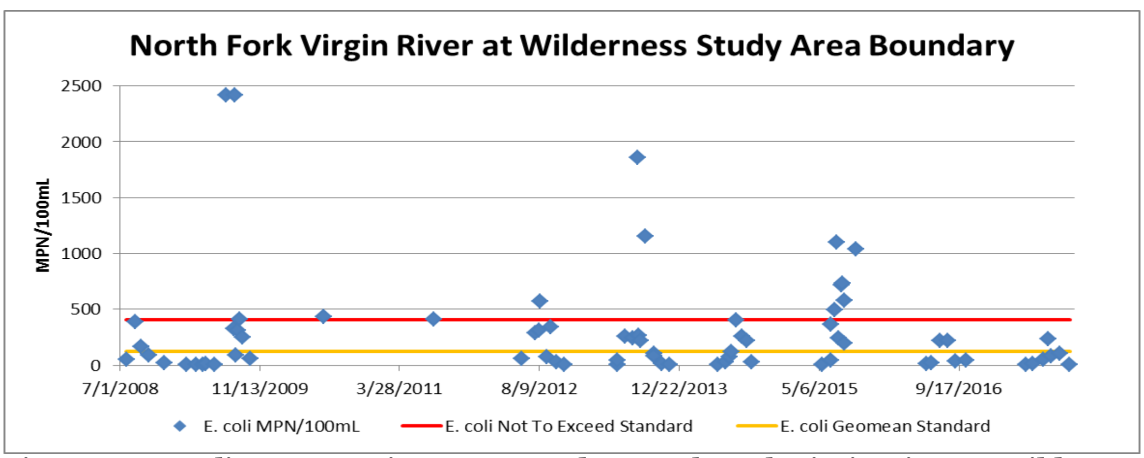


Figure 21: *E. coli* concentrations measured at North Fork Virgin River at Wilderness Study Area Boundary from 2008-2017.

The North Fork Virgin River at Wilderness Study Area Boundary site is approximately 1 mile downstream of the End of Road site. It has been a long term monitoring location for many years but accessibility is difficult so it was not selected as the site to use for more detailed TMDL data analysis.

Irrigation Return Flow Influence on In Stream Water Quality

There are many pastures in the North Fork Virgin River watershed that are flood irrigated where water is diverted from the river and conveyed down canals along the sides of fields and released across them at various intervals. Flood irrigation is an effective and inexpensive means of watering but is also a means for transporting sediment, nutrients and fecal material from pastures into receiving waters. Where irrigation water is applied in excess of what can be absorbed by the soil it flows over the surface and back into the stream; these are called return flows.

The goal of the intensive monitoring effort throughout the watershed was to better identify and characterize potential sources of bacteria to the river, especially in the areas where exceedances had regularly been measured. Sampling of return flows provides an indication of the magnitude of the *E. coli* load from these waters to the stream. One or two return flow sites were sampled opportunistically when they were observed on each sampling day. Five irrigation return flow sites were sampled often enough to report (Table 11). The return flows were collected at the point where they spilled from the pastures into the river. In many instances the *E. coli* concentrations exceeded the upper reporting limit of the Idexx Colilert method used for monitoring, so dilutions were often made to allow determination of the actual concentration. The table below shows the results from 2010-2017 for those five irrigation return flows.

Site Description	n	Minimum *E. coli* concentration (MPN/100mL)	Maximum *E. coli* concentration (MPN/100mL)	Geometric Mean All Samples (MPN/100mL)
Return Flow South at Narrows Trailhead	18	185	11,199	661
Return Flow North at Narrows Trailhead	26	12	7,270	238
Return Flow South upstream of old cabin	5	2	17,329	180
Return Flow South at Cabin on BLM	19	6	5,794	396
Return Flow above WSA at End of Road	27	5	6,131	581

Table 11: Summary of *E. coli* Data from Irrigation Return Flows, 2010-2017

It was common to see exceedances of the *E. coli* standard in the river downstream of return flows. On some instances when concentrations were well below the standard at the Bridge site above the pastures, concentrations exceeded the standard just 3 miles downstream at the End of the Road if there were return flows. This is likely dependent on how long the water has been flowing over the pastures and how recently pastures have been grazed by cows and wildlife. Additionally, sometimes water is discharged from the downstream end of the ditch and has not been distributed across the pastures.

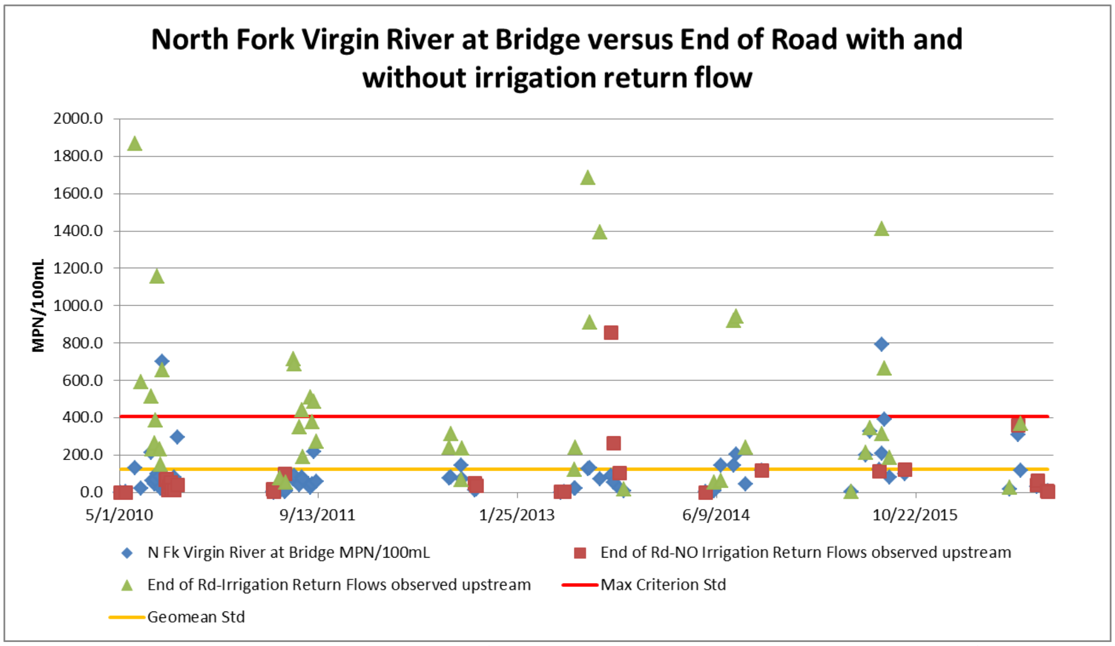


Figure 22: Bridge site versus End of Road site with and without return flow.

4.4.1 Water Quality Analysis for End of Road Compliance Site

To ensure protection of recreation and drinking water uses of assessed waterbodies of the state, DWQ considers three scenarios to assess *E. coli* data based on sampling frequency and the number of collection events at a monitoring location:

- **Scenario A:** A seasonal assessment against the maximum criterion
- **Scenario B:** A 30-day geometric mean assessment
- **Scenario C:** A seasonal geometric mean assessment

Scenario A:

Exceedances of the acute standard for 2A waters have been measured at the End of the Road monitoring location since 2010. When considering all collection events from recreation seasons (May-October) since 2010, 24% exceed the acute standard (i.e., maximum criterion). This has resulted in non-attainment of the frequent primary contact beneficial use and inclusion on the Utah 303(d) list since April 2010.

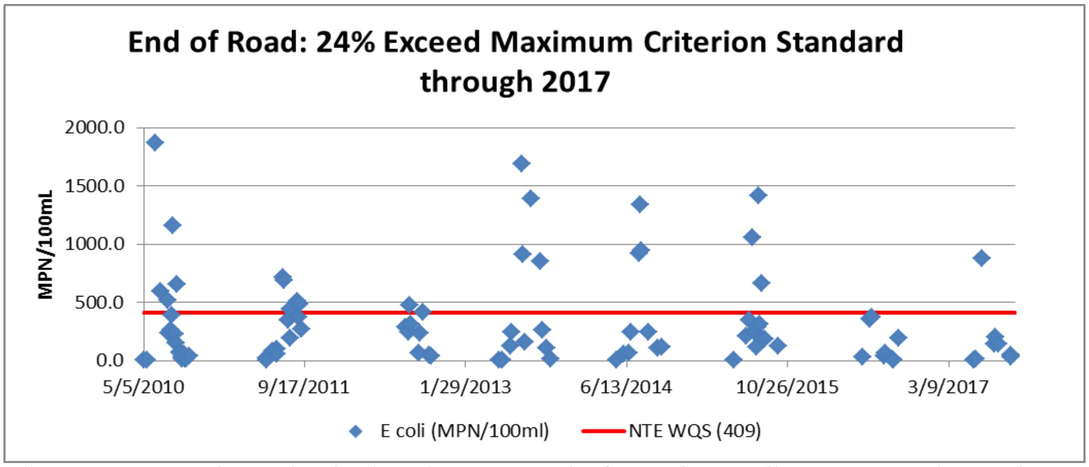


Figure 23: North Fork Virgin River at End of Road *E. coli* concentrations above maximum criterion standard

Scenario B:

To assess against this scenario there must be a minimum of 5 samples collected in a 30-day period, which requires very intensive monitoring throughout the entire recreation season. Exceedances of the 30-day geometric mean assessment were measured at the End of the Road monitoring location in 2010 five times, once in 2011 and five times in 2015.

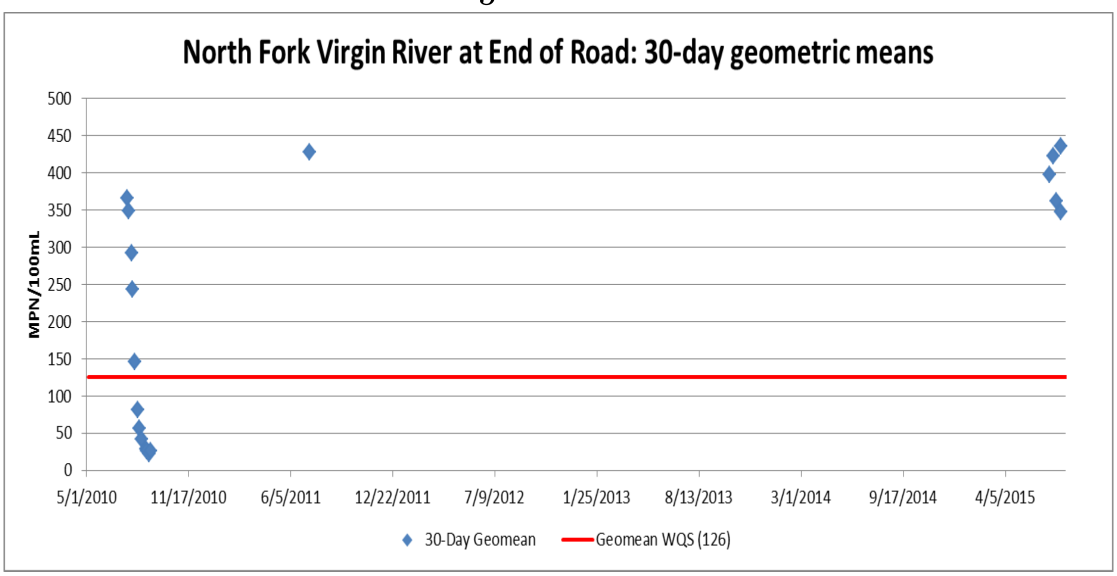


Figure 24: 30-day geometric means for North Fork Virgin River at End of Road

Scenario C:

Exceedances of the chronic recreation season geometric mean standard for 2A waters have been measured at the compliance point monitoring location in 4 of 7 years since 2010. This has resulted in repeated non-attainment of the frequent primary contact beneficial use.

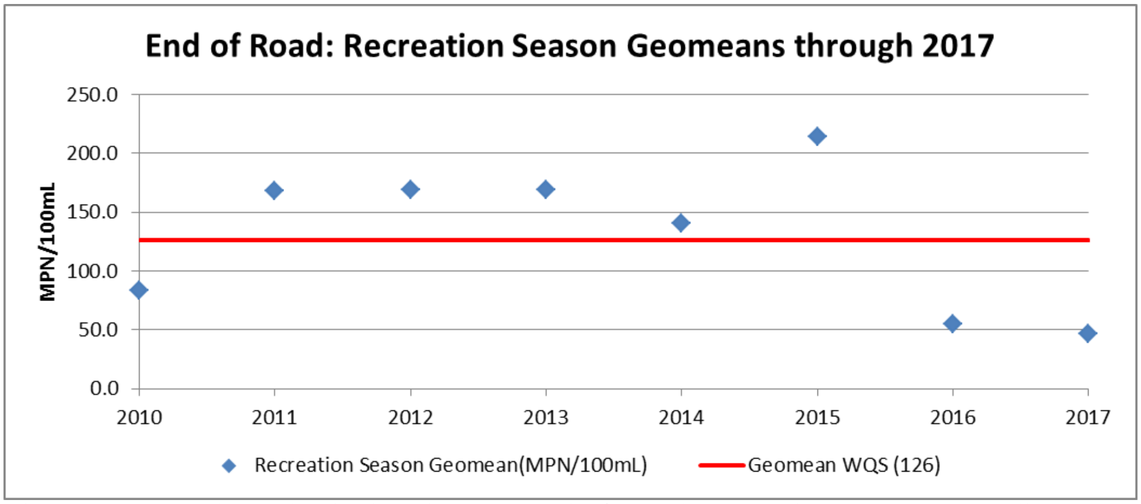


Figure 25: North Fork Virgin River at End of Road recreation season *E. coli* geometric means from 2010-2017

4.4.2 Water Quality Assessment for Temple of Sinawava

Scenario A:

Exceedances of the acute standard for 2A waters have rarely been measured at the Temple of Sinawava monitoring location since 2010. When considering all collection events from recreation seasons (May-October) from 2010-2017, 8% exceed the standard. That is not enough to result in impaired status for the lower North Fork Virgin River Assessment Unit.

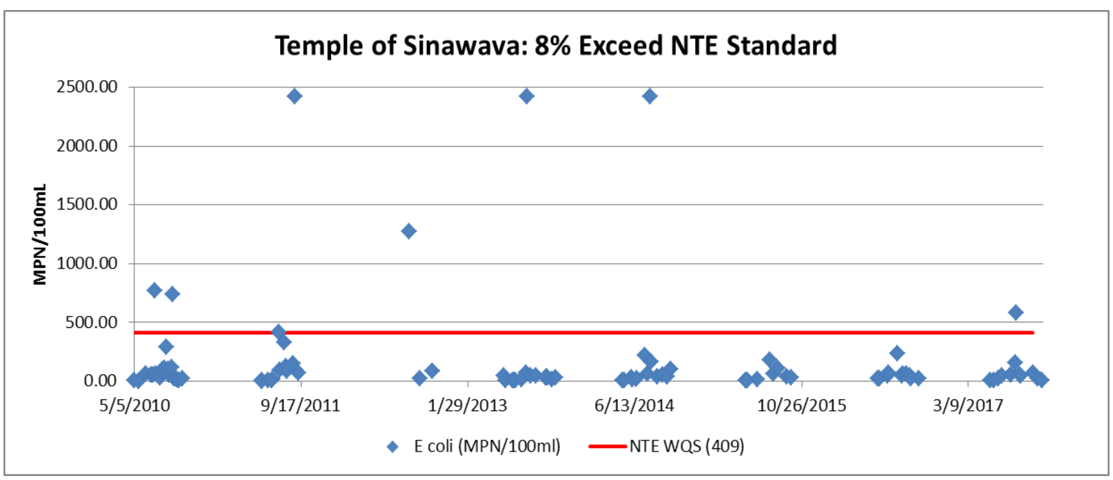


Figure 26: North Fork Virgin River at Temple of Sinawava *E. coli* concentrations above maximum criterion standard

Scenario B:

Exceedances of the 30-day geometric mean assessment were measured at the Temple of Sinawava monitoring location once in 2010 and once in 2011.It is this assessment scenario that led to the listing of this downstream North Fork Virgin River assessment unit.

Scenario C:

No exceedances of the chronic recreation season geometric mean standard for 2A waters have been measured at the Temple of Sinawava monitoring location.

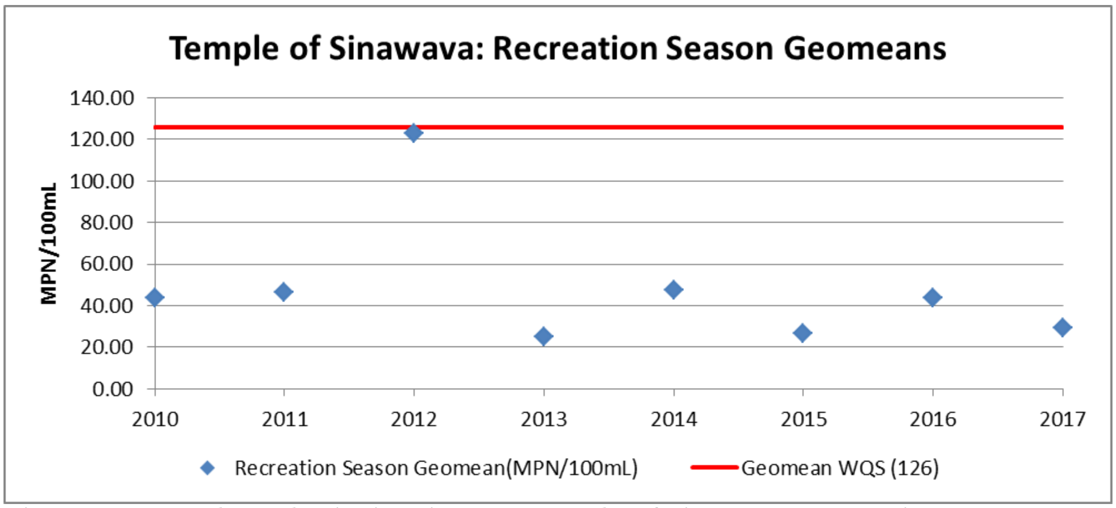


Figure 28: North Fork Virgin River at Temple of Sinawava recreation season geometric means from 2010-2017.

5.0 TMDL

5.1 Calculation of Loading Capacity and Existing Load

The loading capacity is the amount of pollutant that can be assimilated by a waterbody while still meeting water quality standards, thus protecting the waterbody's designated beneficial uses. It is calculated by multiplying the water quality standard, the corresponding flow, and a conversion factor to determine the allowable pollutant load. The existing load is the amount of pollution that is observed in the river at the time of sample collection. It is calculated by multiplying the pollutant concentration, flow, and a conversion factor. If the existing load exceeds the loading capacity, the beneficial use is impaired and loading must be reduced. The loading capacity is equivalent to the Total Maximum Daily Load (TMDL) and is allocated among identified sources including wasteload allocations (point sources) and load allocations (nonpoint sources), and a margin of safety. There are no point source wastewater discharges in this basin, so all of the loading is considered nonpoint.

5.2 Load Duration Curve

Load Duration Curves (LDC) were calculated for the North Fork Virgin River at End of Road (4951268) and North Fork Virgin River at Temple of Sinawava (4951199) monitoring sites that compare existing water quality conditions and the conditions required to meet water quality standards. A LDC identifies the allowable and existing loads, uses data for all flow and loading conditions, and provides insight into critical conditions. LDCs are well suited for analysis of periodic monitoring data collected by grab samples.

The LDC calculation included the following steps:

1. Available flow data was used to generate a flow frequency table that consisted of ranking all the observed flows from the smallest observed flow to the greatest observed flow and plotting all the values to create a flow duration curve (Figure 29).
2. The flow duration curve was translated into a load duration curve (Figure 30) by multiplying each flow by the water quality standard and plotting the results. This curve represents the loading capacity for each observation.
3. Then, each instream sample value was converted to a daily load by multiplying the observed concentration by the corresponding observed flow.

4. The difference between the observed load and loading capacity for each flow regime quantifies the necessary load reductions during critical conditions. Both observed loads and loading capacities for conditions ranging from high flow to low flow were then graphed.
5. Loads plotted above the load duration curve represent exceedances of the loading capacity. Loads plotted below the curve represent allowable daily loads and are in attainment of the water quality standards.

The load duration curve approach identifies the major issues contributing to the impairment and differentiates between various types of sources. Loads that plot above the allowable load curve in the 1-10% flow ranges (rare high flow conditions) represent hydrologic conditions of flooding. Loads plotting above the curve between the 10-60% flow ranges likely reflect precipitation driven contributions. Those plotting above the curve in 70-90% flow ranges are indicative of constant discharge sources. Loads that plot above the curve in greater than 90% of all recorded flows reflect hydrologic conditions of drought.

Observed flows from May 2009 through October 2016 were ranked in order of magnitude and each flow was assigned a percentile that reflects the chance of a flow greater than or equal to it. Each flow was then multiplied by the 126 MPN/100 mL standard (geometric mean) to calculate a corresponding maximum loading limit for each flow. The individual lines were plotted to present a loading capacity line by flow percentile, as shown in Figure 27.

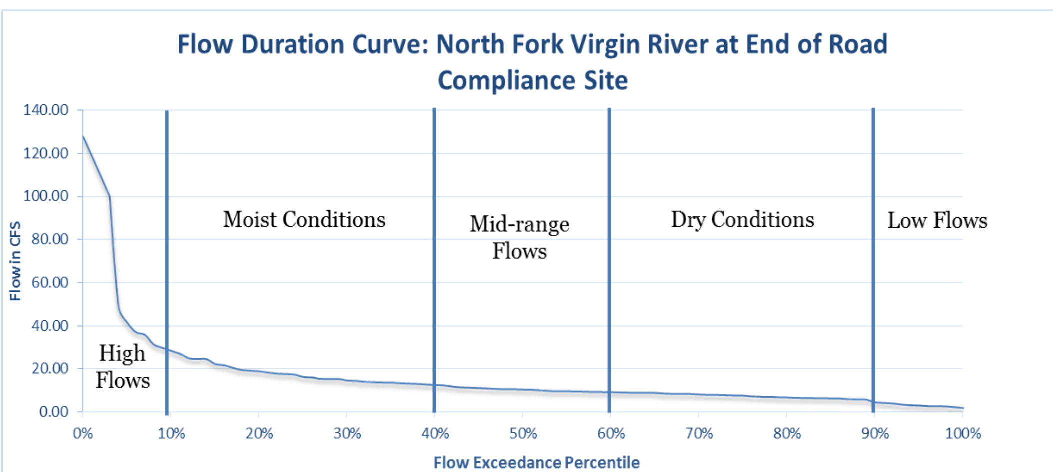


Figure 29: Flow duration curve for the North Fork Virgin River at the End of the Road

Flows at the End of Road site ranged from a maximum of 127 CFS to a minimum of 1.7 CFS. One of the limitations of the monitoring of this area is that it is inaccessible during the early spring runoff because of lingering snowpack or mud on the roads to the sites. As a result, this flow duration curve does not capture the peak flow events.

Another limitation of the dataset is inaccessibility of monitoring locations during precipitation events. In the upper North Fork Virgin watershed the roads become slick and impassible so samples can't be collected until several days following a storm event. Surface runoff following rain events can be one of the most significant transport mechanisms of sediment and bacteria. *E. coli* sampling plans often include targeted monitoring of storm events to quantify loading from precipitation but that was not possible for this study.

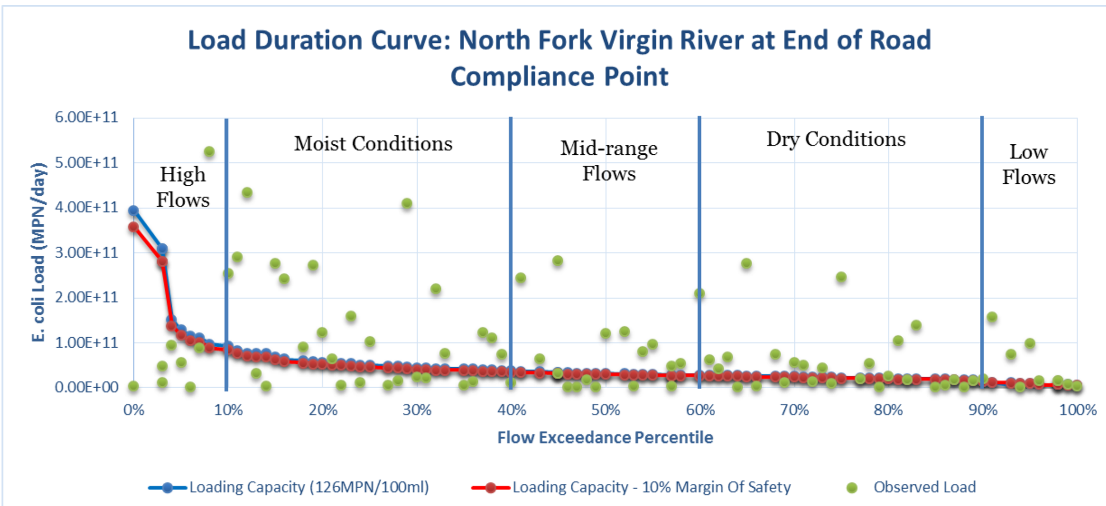


Figure 30: Load duration curve for North Fork Virgin River at End of Road

Loads that plot above the curve indicate an exceedance of the water quality criterion, while those below the load duration curve show compliance. This load duration curve illustrates that exceedances occur at the compliance point during all hydrologic conditions. This suggests that bacteria loading to the river is not driven exclusively by spring runoff or precipitation events. There is consistent loading even in dry to low flow conditions.

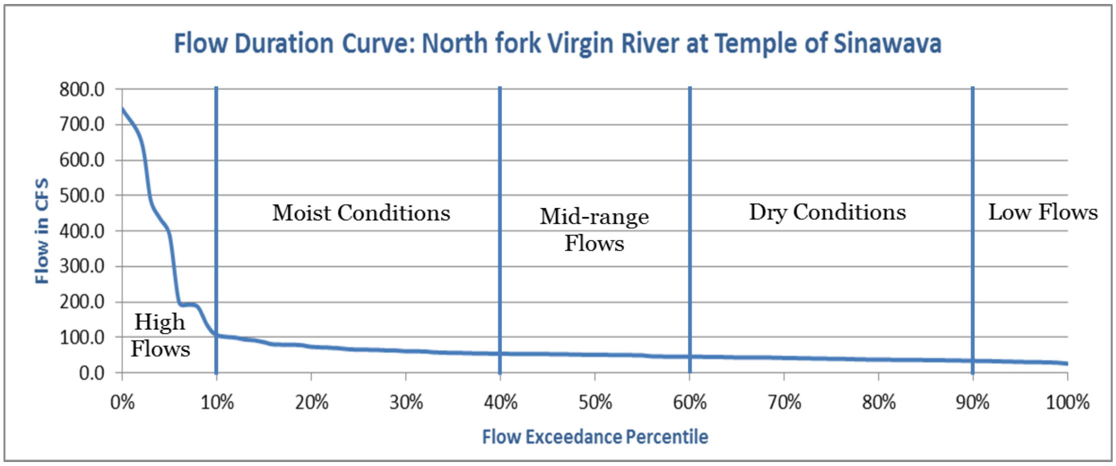


Figure 31: Flow duration curve for North Fork Virgin River at Temple of Sinawava.

Flows for the Temple of Sinawava site were estimated using the downstream USGS flow gage in the park. There are several small tributary streams between the Temple of Sinawava and the gage but there are also multiple diversions so the assumption was made that the difference would be nonconsequential. Flows at the Temple of Sinawava ranged from a maximum of 744 CFS to a minimum of 27 CFS.

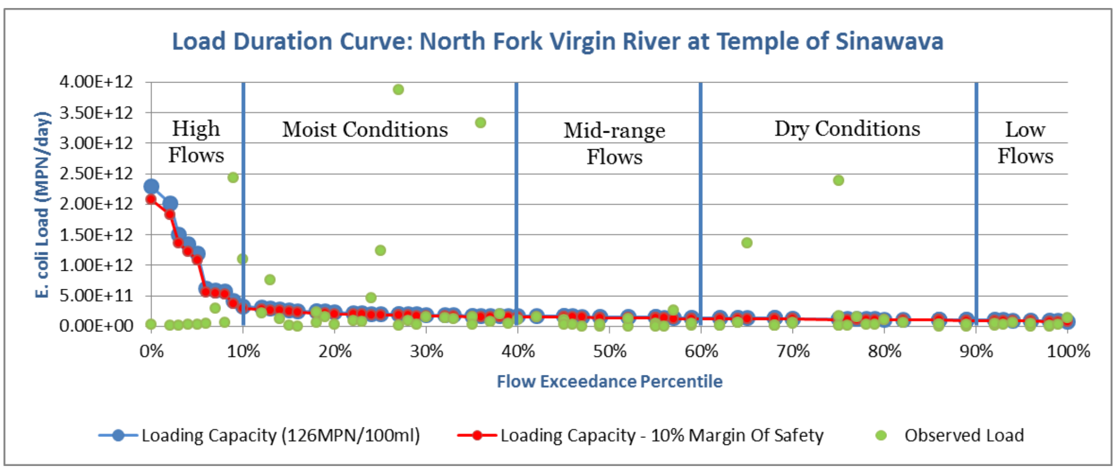


Figure 32: Load duration curve for North Fork Virgin River at Temple of Sinawava

There are only a handful of collection events where observed loading exceeds the loading capacity at the Temple of Sinawava site. Similar to the End of the Road site, loads were measured during different flow regimes indicating the exceedances were not exclusively precipitation event driven or a result of low flow conditions.

5.3 TMDL

TMDL results were calculated using median monthly flows and monthly geometric means of *E. coli* concentrations. The geomean standard of 126 MPN/100mL was used for determination of the Loading Capacity.

E. *coli* loading was evaluated on a monthly basis to determine if certain months were critical, particularly during the defined recreational period of May through October. Results indicate that for the End of the Road site the months of June, July, and August need reductions of 25%, 76% and 49% respectively. For the Temple of Sinawava site July and September need reductions of 11% and 9%. It is anticipated that reductions in loading in the upper Assessment Unit will result in decreased concentrations for the lower Assessment Unit and Temple of Sinawava site, though it cannot be determined at this time whether this will be sufficient to reduce observed concentrations below the loading capacity for all months.

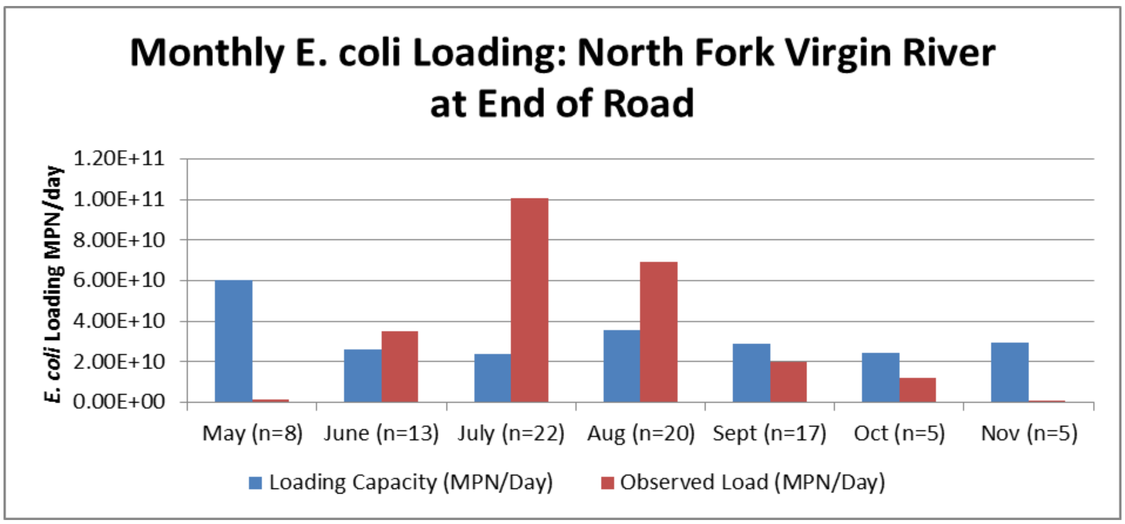


Figure 33: Monthly loading capacity versus observed loading at End of Road monitoring location

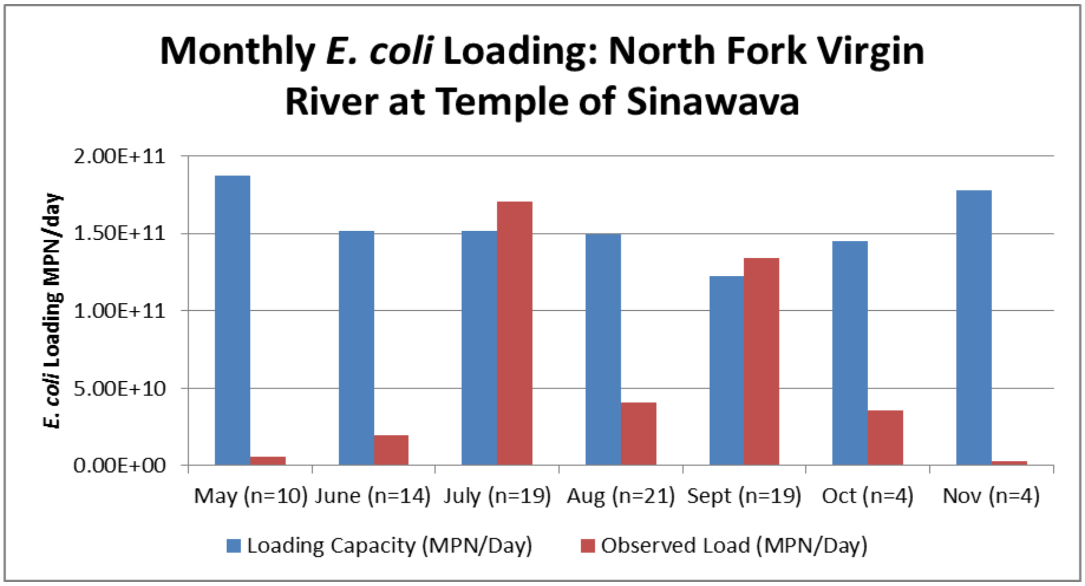


Figure 34: Monthly loading capacity versus observed loading at Temple of Sinawava

5.4 Seasonality

Due to difficulty in accessing the upper North Fork Virgin River watershed in the winter months the majority of the *E. coli* data that exist are from the summer months of June through September. There are some data from October and November that indicate a drop in concentration. That coincides with the cessation of irrigation, removal of cattle from pastures, lack of summer cabin use, and decrease in number of hikers.

The critical season of this *E. coli* TMDL is July because it is the month with the largest necessary percent load reduction for both monitoring locations. Table 12 shows the *E. coli* TMDL for North Fork Virgin River from Deep Creek upstream to the headwaters including the observed loading, margin of safety, loading capacity, and the necessary percent reductions. Table 13 shows the observed loading, loading capacity, and percent reduction needed for the Temple of Sinawava monitoring location which is the compliance point for the lower assessment unit.

Month	Loading Capacity (TMDL) MPN/day based on 30-day geomean, minus 10% Margin of Safety	Margin of Safety (LC*10%)	Observed Load MPN/day based on 30-day geomean	Necessary Reduction
May (n=8)	6.04E+10	6.71E+09	1.39E+09	0%
June (n=13)	2.62E+10	2.92E+09	3.52E+10	25%
July (n=22)	2.40E+10	2.66E+09	1.01E+11	76%
Aug (n=20)	3.55E+10	3.94E+09	6.93E+10	49%
Sept (n=17)	2.89E+10	3.21E+09	2.00E+10	0%
Oct (n=5)	2.45E+10	2.72E+09	1.21E+10	0%
Nov (n=5)	2.92E+10	3.25E+09	7.92E+08	0%

Table 12: Loading capacity, margin of safety, observed loading and necessary percent reductions based on North Fork Virgin River at End of Road monitoring location.

Month	Loading Capacity (TMDL) MPN/day based on 30-day geomean, minus 10% Margin of Safety	Margin of Safety (LC*10%)	Observed Load MPN/day based on 30-day geomean	Necessary Reduction
May (n=10)	1.87E+11	2.08E+10	5.63E+09	0%
June (n=14)	1.51E+11	1.68E+10	1.94E+10	0%
July (n=19)	1.52E+11	1.69E+10	1.71E+11	11%
Aug (n=21)	1.49E+11	1.66E+10	4.10E+10	0%
Sept (n=19)	1.22E+11	1.36E+10	1.34E+11	9%
Oct (n=4)	1.45E+11	1.61E+10	3.58E+10	0%
Nov (n=4)	1.78E+11	1.98E+10	2.91E+09	0%

Table 13: Loading capacity, margin of safety, observed loading and necessary percent reductions based on North Fork Virgin River at Temple of Sinawava monitoring location.

6.0 SOURCE ASSESSMENT

This section provides a summary of sources of *E. coli* that likely contribute to water quality impairments in the North Fork Virgin watershed. Typically, sources are characterized as either point or nonpoint sources, where point sources are spatially discrete and regulated under the Utah Pollution Discharge Elimination System (UPDES) and nonpoint sources are spatially distributed and not regulated. Because there are no point sources located in the North Fork Virgin River watershed, this source assessment will focus solely on nonpoint sources such as wildlife, livestock, and humans (including both recreation and septic systems). A summary of each source is provided below along with an estimate of the relative contribution of each.

6.1 Point Sources

There are no point source discharges covered under UPDES permits in the North Fork Virgin River watershed.

6.2 Nonpoint Sources

Nonpoint source pollution refers to diffuse contamination that does not originate from a single distinct source but is an accumulation of small sources of pollution that exist throughout the watershed. Nonpoint source pollution, like *E. coli*, enters waterbodies through surface water runoff, such as rainfall or snowmelt, or directly into streams. Potential contributors of nonpoint source pollution within the North Fork Virgin River Watershed are wildlife, livestock, and humans. To gain a better understanding of *E. coli* sources in the watershed, information was gathered and assessed from the National Park Service, Bureau of Land Management, Utah Division of Wildlife, Southwest Utah Public Health Department, and local landowners. The intent of the assessment was to qualitatively evaluate potential sources in such a way that future funds and resources can be directed in the most efficient way possible.

6.2.1 Humans

Recreation

Zion National Park is an internationally known tourist destination with visitation numbers increasing annually. Many of the park visitors are drawn to recreate in the water especially during the summer months when temperatures are high.

The Zion Narrows hike originates in the upper watershed where *E. coli* exceedances have been measured. Every year, thousands of people obtain permits from the Park office to hike the 16 mile Narrows trail. Many of them camp overnight in the Narrows.

At the downstream end of the Zion Narrows visitors to the Temple of Sinawava site at the end of the road in Zion National Park do not need a permit to hike upstream. Park staff have estimated that there were more than 400,000 visitors at the Temple of Sinawava site in 2016 and on an average summer day more than 2,000 hikers enter the water at that location and hike some distance upstream. That number has increased substantially from the 1990's when the number of visitors was limited by the number of parking spaces, but after 2000 is limited by the much larger capacity of the shuttle system to deliver visitors. That number is likely to increase annually in correlation with record setting increases in visitation to the Park. There are modern restroom facilities at the trailhead in the Park; however, once hikers head up the river there are no additional facilities available. While fecal matter can be seen on the few vegetated terraces that provide protection from sight it is not feasible to build any restrooms within the Narrows corridor due to the high likelihood of flash floods through the canyon and the difficulty of access for construction and servicing.

Figure 35: Hikers in the North Fork Virgin.

Numbers from 2016 specific to the Narrows trail indicate that more than 3,000 permits were issued for camping along the trail and more than 2,000 hikers through-hiked the 16 miles in one day. There is a restroom available to hikers at the start of the Narrows hike at Chamberlain Ranch trailhead. Hikers also receive "wag bags" when they get their permits to collect and securely seal in fecal waste so it can be properly disposed of upon completion of the hike. Informal surveys of permitted hikers exiting the Narrows indicate that some do not utilize the bags and are therefore likely defecating and burying it near the campsites.

Precipitation events are known to flush pollutants overland and into waterways so it's expected that *E. coli* concentrations increase after storm events as a result of the improperly disposed human waste. This would be in addition to the contribution of other fecal matter from livestock and wildlife on the watershed. Most of the in-stream hiking takes place from May through October so it's also expected that those months would have the highest amount of bacteria loading to the river from humans.

Septic Systems

When properly designed and maintained, septic systems pose no significant threat to surface water quality. However, failing or improperly designed or maintained systems must be considered as a potential source of bacteria to waterways.

The Southwest Utah Health Department records show 163 individual septic systems in the North Fork Virgin River watershed. This number does not include any of the large systems in the area such as Clear Creek Canyon Ranch, Zion Frontier Resort or Zion Mountain Resort, or the East Zion Special Service District evaporative lagoon sewer system because these systems are located on a part of the watershed that joins the North Fork downstream of the reaches considered in this evaluation. It is also likely there may be some unpermitted systems that predate the permitting process. There is currently no map available for these septic systems; however, the state is working on compiling all septic system information into a database such that mapping will be an option in the future. For this study, it is not possible to derive an accurate estimate of where all septic systems are located and their proximity to the river. Casual observation indicates that most are located high in the watershed and along the primary access roads which would place them near the major stream channels.

Despite the lack of information on individual septic system locations, we do have monitoring data that indicates that septic systems are not a significant contributor in the watershed. For instance, there is a cluster of seasonal cabins near Navajo Lake upstream of the three upper most monitoring locations on the North Fork Virgin River. Very few exceedances of *E. coli* have been measured in the last 7 years at those three locations indicating that loading from the cabins is minimal. Furthermore, cabin usage increases during the recreation season so it is likely that monitoring conducted during that time would reflect failing systems if present.

Outhouses

An outhouse built directly over one of the irrigation canals was in place until the summer of 2015 (Figure 36). It was located approximately ¼ mile upstream of the Zion Narrows Trailhead. The outhouse was used, at least intermittently, as fresh fecal matter was observed in it on some occasions. Samples were collected from the canal running underneath it which leads directly to the river. There was no significant difference in *E. coli* concentration between samples collected above and below the outhouse indicating that it was not a major contributor to *E. coli* contamination in the river. Figure 37 illustrates concentrations measured in the irrigation canal approximately 10 feet downstream of the outhouse. While some exceedances of the single sample maximum of *E. coli* occur, the majority of samples are less than the water quality criteria. Furthermore, now that the outhouse has been removed, it is no longer considered a source. If any additional outhouses are identified in the watershed they must comply with Utah Rule R317-560: Rules for the Design, Construction, and Maintenance of Vault Privies and Earthen Pit Privies. R317-560-4.2 states that all vault privies and earthen pit privies shall be maintained in a satisfactory manner to prevent the occurrence of a public health nuisance or hazard or to preclude any adverse effect upon the quality of any waters of the State.

Figure 36: Outhouse constructed over irrigation canal. This structure was removed in 2015.

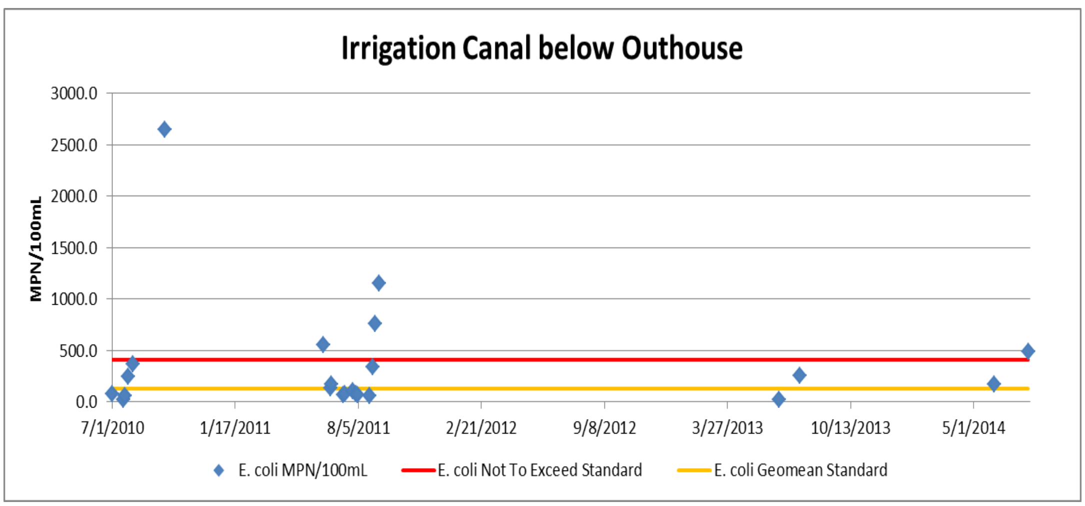
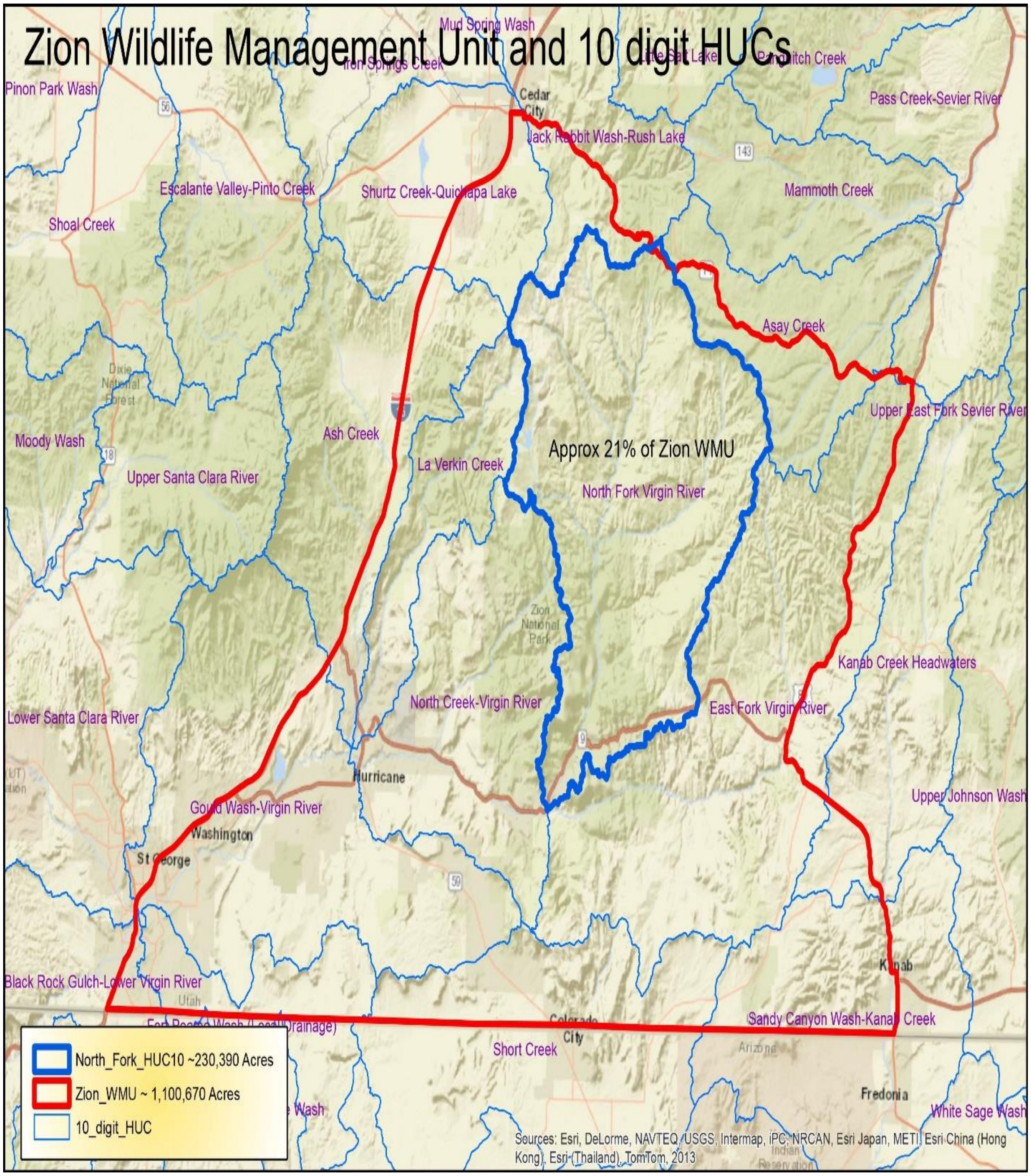


Figure 37: *E. coli* concentration in the irrigation canal below the outhouse.

6.2.2 Wildlife

The Utah Division of Wildlife Resources' Cedar City office (UDWR) provided population estimates for big game for the Zion Management Unit (personal communication between Jason Nichols [UDWR] and Amy Dickey [UDWQ], March 29, 2017). The Zion Management Unit boundaries are Highway 14 to the north, Highway 89 to the east, the Arizona border to the south and I-15 to the west (Map 8). The North Fork Virgin watershed accounts for approximately 21%

of the management unit. UDWR estimates that there are 18,300 deer, 800 elk and 800 bighorn sheep (Table 15) in the Zion Management Unit. There are no estimates available for turkeys, upland game, or waterfowl.



Map 8: Utah Division of Wildlife Resources Zion Wildlife Management Unit.

Wildlife Type	Estimated Population in Zion Management Unit	Estimated Population for North Fork Virgin River Watershed (21% of Unit)
Deer	18,300	3,843
Elk	800	168
Bighorn Sheep	800	168

Table 15: Wildlife population estimates for Zion Management Unit.

6.2.3 Livestock

Livestock grazing occurs on both private and federal land in the upper North Fork Virgin River watershed every summer. In many cases livestock are in close proximity to the river and often have direct access to the river for water. There are also instances of livestock grazing on pastures that are actively being irrigated with return flows entering the river.

Private Land

Utah Department of Agriculture and Food planners provided an estimate of livestock numbers on private property (Jake Benson and Wally Dodds, May 2017). Landowners are not required to report on the number of animals on their property, and the numbers vary from year to year depending on landowner choices. Animals are brought in to graze from June 10th through October 5th. The upper watershed is not conducive to year-round grazing due to the snowpack and lack of accessibility. Estimates for number of animals grazing private land are provided below in Table 16.

Animal Type	Estimated number in watershed per season
Cows	1,855
Horses	70
Sheep	3,300

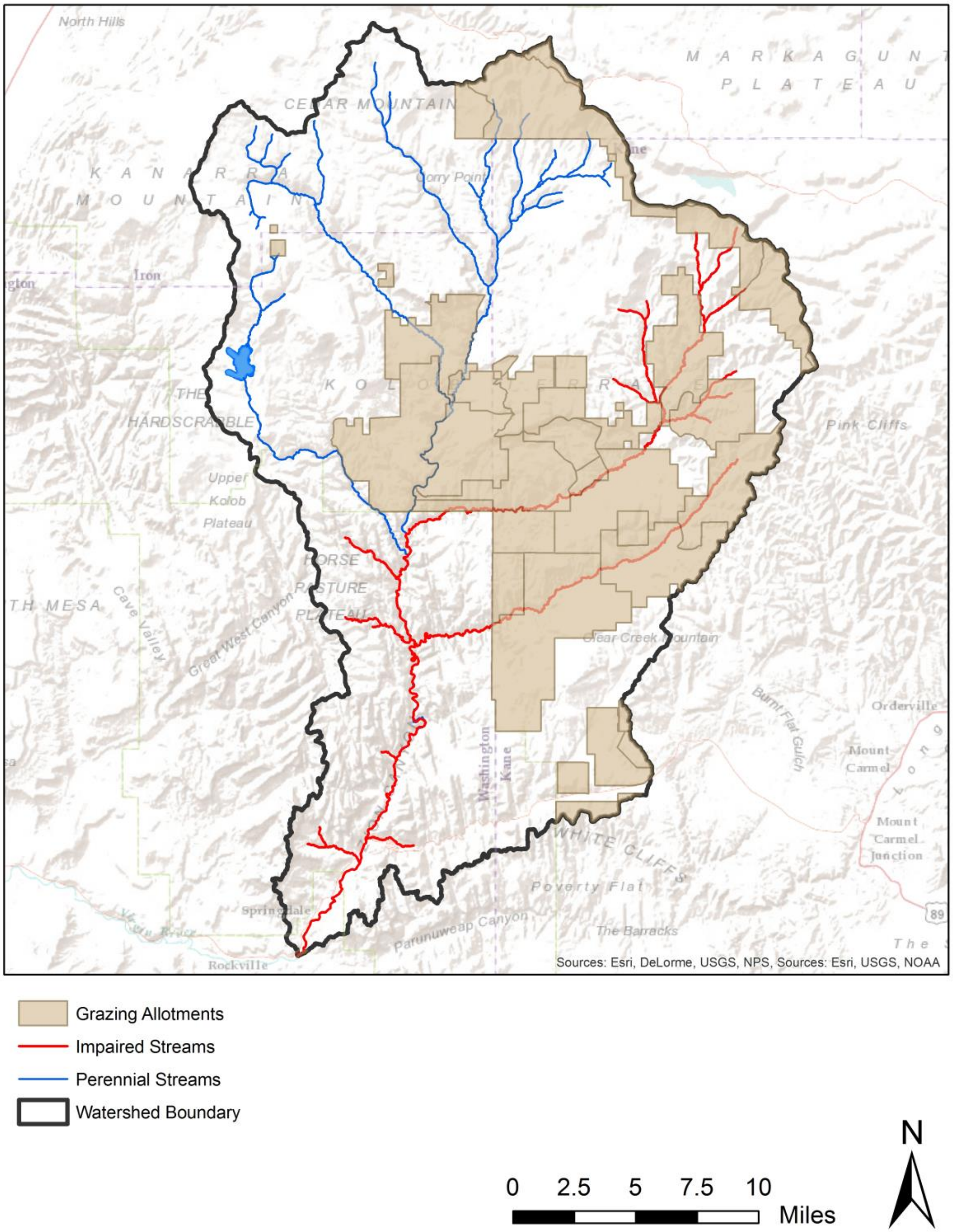
Table 16: Livestock estimates on private property.

Public Land

The BLM manages rangelands throughout the west for the use of wildlife and livestock. The rangelands are divided into allotments and pastures for management purposes. There are thirteen livestock grazing allotments within the North Fork Virgin River watershed (Map 9). Kanab BLM Range Management staff have been very involved in this study since its inception. They have collected and analyzed water quality samples, worked with permittees on allotment management improvements and participated in stakeholder and technical advisory committee meetings. They provided the estimates shown below of livestock numbers for the allotments that are within the watershed. Animal Unit Months are defined as the amount of forage needed by an "animal unit" (AU) grazing for one month. The quantity of forage needed is based on the cow's metabolic weight, and the animal unit is defined as one mature 1,000 pound cow and her suckling calf. Various other types of stock are assigned AUM equivalents based on size and consumption. For example, a mature bull is the equivalent of 1.3 AU, a yearling steer or heifer is 0.67 AU and a weaned calf is 0.5 AU.

Allotment	#	Livestock	Season of Use	Animal Unit Months
Cave Creek	3	Cattle	5/16-10/15	15
Cogswell Point	2	Cattle	5/1-9/30	10
Gordon Point	13	Cattle	6/1-10/1	40
Hay Canyon	10	Cattle	5/16-10/15	50
Hogs Heaven	10	Cattle	5/16-10/15	50
Lower Herd	5	Cattle	6/1-10/31	25
Lower North Fork	2	Cattle	5/1-9/30	10
Neuts	29	Cattle	5/16-9-30	76
North Fork	16	Cattle	5/16-10/15	19
Orderville Gulch	40	Cattle	5/16-10/15	201
Table Mountain	89	Sheep	5/16-10/15	90
Upper North Fork	2	Cattle	6/1-10/31	10
Zion Park	7	Cattle	5/1-7/1	14

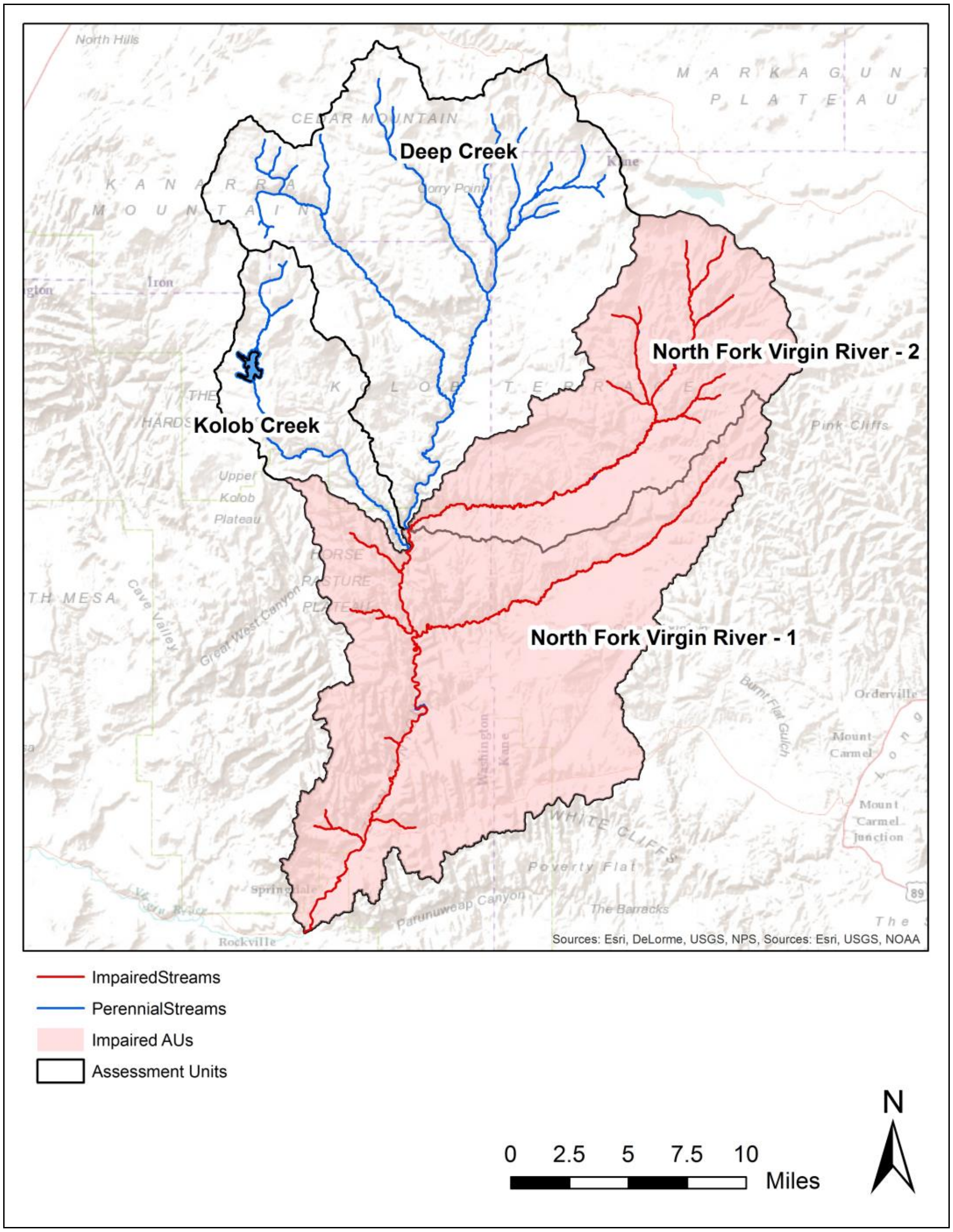
Table 17: Livestock within North Fork Virgin River watershed BLM Allotments.



Map 9: BLM grazing allotments in the North Fork Virgin River watershed.

6.3 Source Assessment Summary

An evaluation of bacteria loads by source was conducted using the bacteria production rate per animal and the number of animals in the watershed. It should be noted that this assessment is specific to the impaired upper and lower assessment units in the North Fork Virgin River watershed and does not include the Deep Creek or Kolob Creek units where data were not available (Map 10). The intent of this evaluation was to compare the different sources relative to one another and provide evidence for what is likely contributing to the impairment such that appropriate implementation measures can be taken. Several assumptions were used in this assessment, all of which are described below.



Map 10: Impaired Assessment Units in the North Fork Virgin River watershed.

6.3.1. Bacteria Production

Bacteria production rates vary by animal with cows and horses producing the largest bacteria loads and deer producing the lowest (Table 18) (Zeckoski et. al. 2005). In cases where literature estimates were not available (i.e., elk and bighorn sheep), estimates from livestock were used. For instance, the bacteria production rate for elk was assumed to be the same as a cow based on their similar weights.

Animal*	**Bacteria Production Rate (cfu†/animal/day)**
Humans	2.00×10^{9}
Elk	3.30×10^{10}
Bighorn Sheep	1.20×10^{10}
Deer	3.50×10^{8}
Cows	3.30×10^{10}
Sheep	1.20×10^{10}
Horses	4.20×10^{10}
*all literature values were taken from Zeckoski et. al. 2005 †cfu = colony forming unit	

Table 18: Bacteria production by animal.

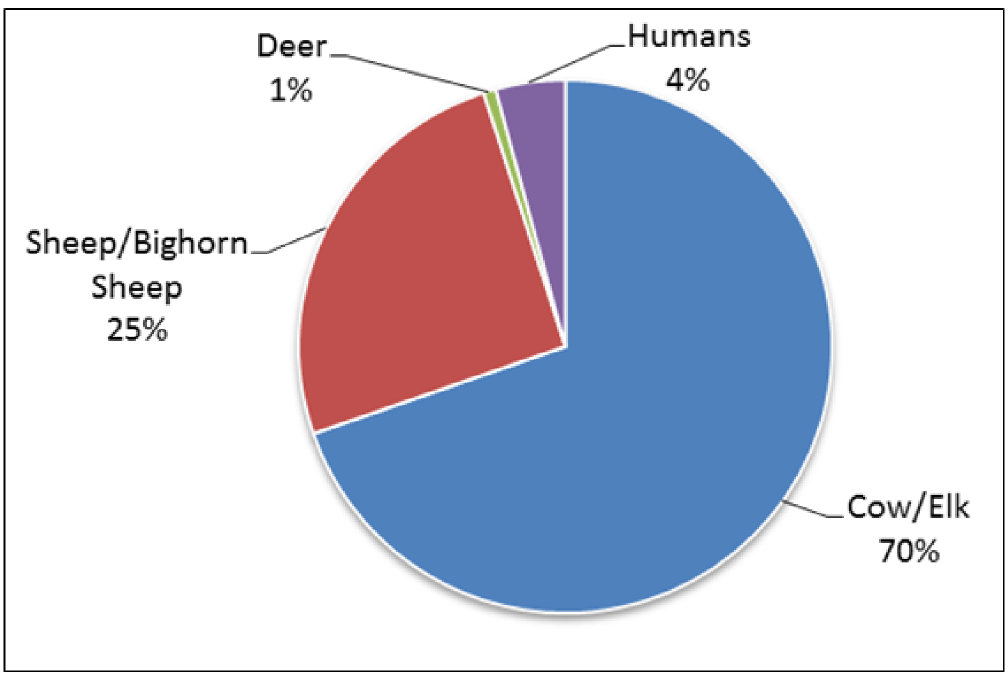


Figure 38: Bacteria production by animal (cfu/animal/day).

6.3.2. Source Assessment

Bacteria production rates from Table 18 were coupled with the number of animals in the watershed to identify the relative contribution of bacteria by source during the recreation season. The number of animals in the watershed per source was estimated based on available data. For wildlife, 50% of the DWR estimates for the wildlife management unit were used. For livestock, the private grazing and public grazing numbers were summed to get a total number of cows, sheep, and horses. For humans, the number of septic systems plus the park service permitting and visitation information were summed to obtain a total human number.

Bacteria production was then summed by source to determine the relative contribution of humans versus livestock versus wildlife (Figure 39). According to this analysis, livestock are the biggest contributors of bacteria at 78% compared to wildlife at 15%, and humans at 7%.

Animal	**Bacteria Production Rate (cfu/animal/day)**	**Number of Animals in the Watershed**	**Bacteria Production (cfu/source/ rec season)**
Humans	2.00×10^{9}	4,969	1.80×10^{15}
Elk	3.30×10^{10}	800	2.43×10^{15}
Bighorn Sheep	1.20×10^{10}	800	8.83×10^{14}
Deer	3.50×10^{8}	18,300	5.89×10^{14}
Cows	3.30×10^{10}	1,994	1.21×10^{16}
Sheep	1.20×10^{10}	3,389	7.48×10^{15}
Horses	4.20×10^{10}	70	5.41×10^{14}

Table 19: Bacteria contribution by source during the recreation season.

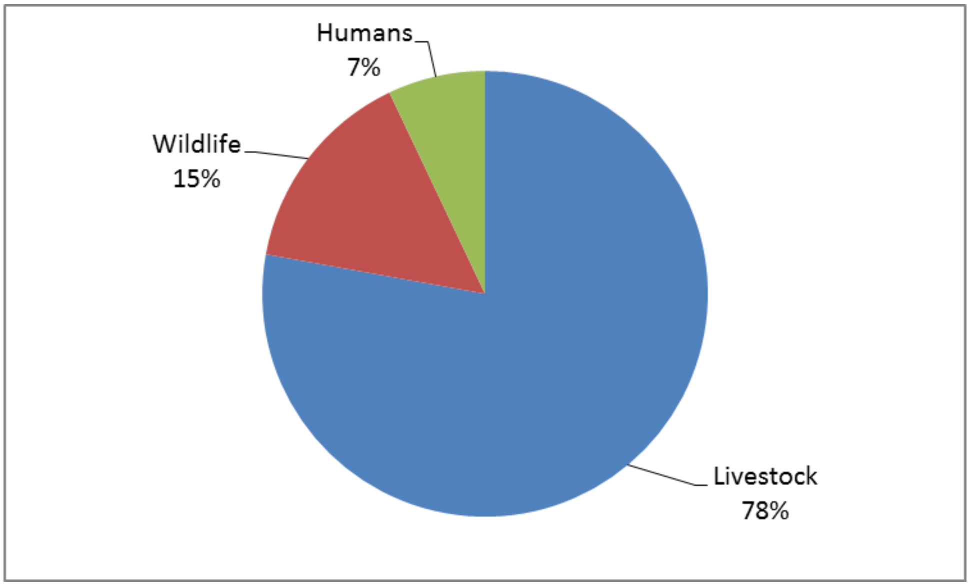


Figure 39: Estimated bacteria contribution by source during the recreation season.

6.3.3 Assumptions and Uncertainty

Several assumptions were used in conducting this source assessment. It was often the case that the number of animals in the watershed was not specific to the watershed area. For example, for wildlife, 50% of the DWR estimate was included as contributing to wildlife source loads because watershed-specific data was not available. However, this analysis does not account for other wildlife species such as waterfowl.

For livestock, private land grazing numbers were estimates and vary from year to year dependent on producer choices.

For septic systems, it is likely that there are more in the watershed than the health department has record of; however, not all septic systems are in proximity to a perennial waterway making them less likely to contribute *E. coli*.

For the human recreation source estimate, assumptions were made about the percentage of humans defecating in or near the river. For overnight permittees and through-hikers, it was assumed that 10% defecate in or near the river whereas for day use hikers, it was assumed that 1% defecate in or near the stream. Also, the day use hikers are likely only influencing *E. coli* loads in the lower Assessment Unit because they do not travel upstream as far as the upper Assessment Unit. Due to the sheer magnitude of visitors to the river every day, if it is assumed that a higher percentage are defecating in or near the river, then our source load contribution changes dramatically. For instance, if we assume 20% of through-hikers and overnight permittees and 10% of day users defecate in or near the stream, then humans account for 34% compared to 18% for wildlife and 48% for livestock. Additional data on human defecation rates would assist in refining these numbers.

6.3.4 Transport Pathways

The source assessment presented above was conducted assuming that bacteria are directly deposited into the river. In reality, it is much more likely that most defecation occurs on the landscape and the majority of the bacteria contained in the feces expire without ever reaching the waterway. A portion of the feces are transported to the river or to irrigation canals during overland flow events. That is particularly true for livestock and wildlife that graze in flood-irrigated fields. Irrigation return flows are present in scattered locations throughout the watershed, particularly in the upper North Fork Assessment Unit. As was described above in Section 4.4, during the irrigation, water is diverted from the river by way of earthen diversion structures and transported through unlined canals along the upper edges of the pastures. Water is diverted from the canals at points along the pasture where it then runs through the grass. Any water in excess of what the soil can absorb becomes return flow that spills back into the river.

Figure 40: Irrigated pasture with return flows along the North Fork Virgin River (note return flows cascading over the banks and into the river at several locations in the photograph).

Due to the complexity of the irrigation network a comprehensive mapping exercise has not been conducted; therefore, at this time it is not possible to determine individual bacteria loads from each return flow. Nor would such an effort be particularly useful because the water distribution points from the ditches are informal and change over time. However, water quality sampling was conducted from 2010-2017 at several return flow locations and show that *E. coli* concentrations are higher than in-stream concentrations thus implicating return flows as a transport pathway for *E. coli* loading into the river. In several cases, samples had to be diluted because they exceeded the maximum reporting limit of the Colilert Method — the EPA approved method for measuring *E. coli*.

7.0 IMPLEMENTATION PLAN

The goal of a TMDL study is to identify the sources of water quality impairment, quantify the load reductions necessary to support the waterbody's beneficial uses and ultimately reduce pollutant loading from controllable sources. An iterative process of public outreach, implementation of control measures, monitoring and evaluation leads to greater stakeholder support for maintaining and expanding water quality improvement efforts.

Implementation of pollution controls will focus on the most cost effective and potentially successful projects first, while mapping out the steps to implement future projects. The effectiveness of water quality improvement projects can be improved by clarifying the following items to stakeholders before projects start:

- Water quality goals
- Date of expected project start up and expected time required to attain water quality standards
- Measurable goals or milestones
- Cost
- Legal or regulatory controls

7.1 Best Management Practices Already Implemented

Prior to the development of this TMDL, various agencies began working with federal land managers and private landowners to improve water quality in the North Fork Virgin River through implementation of Best Management Practices. This section summarizes what practices have already been applied.

Trailhead Vault Toilet

The Division of Water Quality awarded a nonpoint source grant to the Kanab BLM field office to install a vault toilet at the Chamberlain Ranch trailhead in 2011. This is the area where hikers begin the popular 16 mile Zion Narrows hike. Prior to the toilet installation the area was littered with fecal matter and toilet paper. It was not only a threat to public health and a possible source of bacteria to the river during precipitation events, but it was aesthetically unpleasant as well. The vault toilet is maintained by the guide services that shuttle hikers to the trailhead. As a result of this project the overall conditions at the trailhead have greatly improved.

Figure 41: Chamberlain Ranch trailhead pit toilet installed in 2011.

2015 Grazing Management

There are approximately 90 acres of flood irrigated pastures between the Bridge monitoring location and the End of the Road site. Data collected over the past several years indicate that these pastures are a significant source of the *E.coli* loading into the North Fork Virgin River. Of these pastures, approximately 45 acres are private, and the other 45 is administered by the BLM and managed by the grazing permittee.

In an attempt to address the *E.coli* loading from these pastures, a prescribed grazing management plan (Practice 582) was implemented on 45 acres of flood irrigated pastures located on private lands near the Chamberlain Ranch trailhead during the 2015 grazing season. This plan focused on identifying how many animals could be grazed on each individual pasture without over utilizing the feed that was available in each pasture. It also coordinated the timing of the grazing and the timing of the irrigation that was taking place to reduce the likelihood that the manure on the fields would be mobilized by allowing the feces to dry for a period of days to weeks before irrigation water was applied, thus decreasing the amount of *E.coli* entering the stream.

The private landowner had trespass cattle entering into his pastures. To fix this problem the landowner erected, or repaired, approximately 10,000 feet of boundary fence. This helped reduce the number of trespass cattle, and kept them off of the pastures during irrigation turns, thus improving water quality.

In an attempt to improve the grazing the acreage was divided into 4 pastures using electric fence. The cattle were then rotated through these four pastures throughout the year in an attempt to better utilize the available forage, and keep cattle off of pastures while they were being irrigated. While not an objective of this project, an additional benefit of this project was an improved riparian buffer that will act as a filter strip and reduce future *E. coli* loading to the river.

There were challenges associated with implementation of this grazing management plan. Mixed management of the plan, trespass cattle from adjacent properties, inclement weather that prevented access for managers to rotate cattle in a timely manner, and vandalism to electric fence solar panels all made it difficult to determine effectiveness of the grazing management plan.

While no attempt was made to quantify the change in riparian vegetation, the improvements were noticeable throughout the season. The change was also noticeable on Google Earth imagery that was updated during the implementation of the grazing plan this season. The following image shows the improvements along the edge of one of the pastures as a darker shade of green indicating dense cover of pasture grasses.

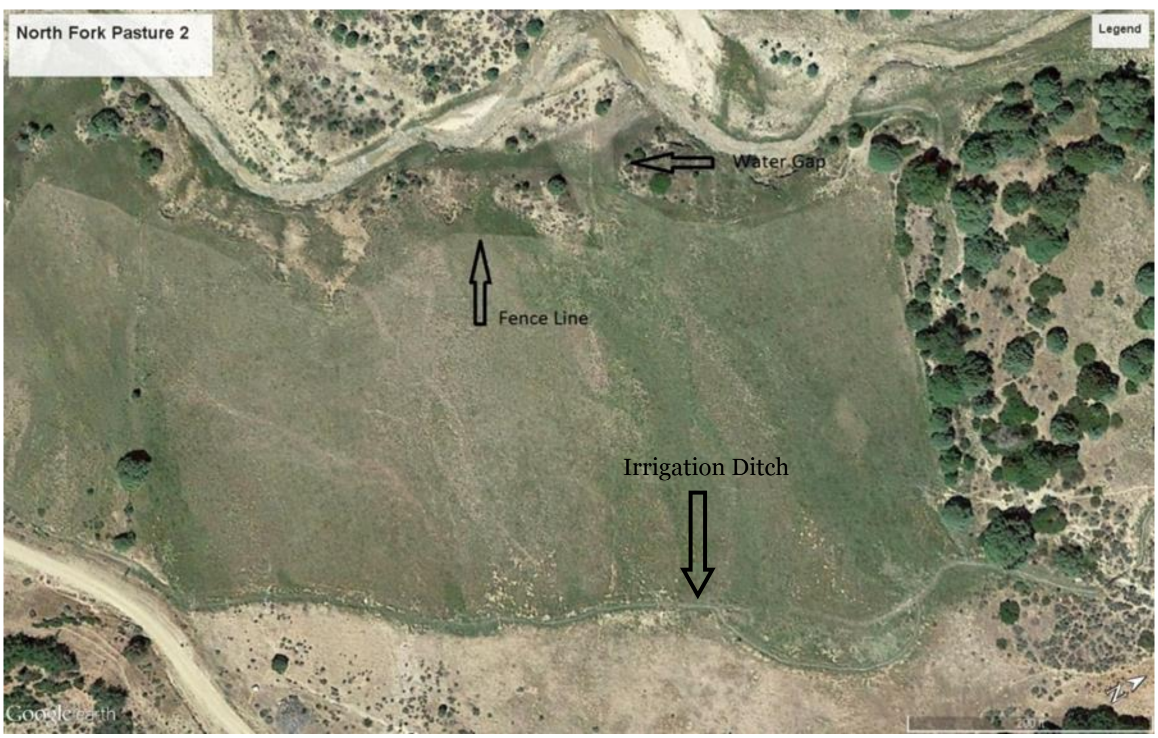


Figure 42. Improvement in riparian condition along pasture as part of grazing management plan.

For the BLM pastures the permittee agreed to flash graze the allotment at the first of the year prior to any irrigation taking place. After the pastures had been flash grazed, the cattle would be removed throughout the remainder of the year while the pastures were being flood irrigated, allowing the pastures to recover. Since 2016 when the flash grazing began, there has only been one E. coli exceedance measured at the End of the Road monitoring site.

There are still opportunities throughout the watershed for improvements in grazing management. Interested landowners can contact the local NRCS office for information about technical and financial assistance for these projects.

Hiker Passage at BLM fence.

About one mile into their Narrows hike, people must pass through a fence that separates the private and BLM pastures, and that gate being left open was a chronic problem. Finding the stray cattle and moving them back to their appropriate pasture was a regular problem for the ranchers, and the cattle on the wrong pasture negated some of the rotation pasturing that was being attempted. In 2016 the BLM installed a hiker "maze" in their boundary fence that permits hikers to pass but excludes cattle eliminating the need for hikers to open and close a gate.

Figure 43. Hiker maze constructed at boundary of private and BLM pastures

Flow measurement devices on lower pastures (Structure for Water Control 587)

Irrigation of many of the pastures in the upper watershed is accomplished through flooding. In many instances there are no flow measurement devices at the points of diversion so water in excess of the approved water right may be diverted to increase the effectiveness of the process. That has the potential to result in increased irrigation return flows.

During the dry years of 2014 and 2015 flows in the Virgin River were inadequate to meet the needs of all water users, and as a result the Utah Division of Water Rights required junior water users of surface water to cease their diversions. As part of this action all water users affected by this order were required to install flow control gates and measuring devices on surface diversions. Two flow measurement devices were installed on the BLM property in 2016.

Irrigators throughout the watershed will be encouraged to install these measurement and control devices. Diversions at Chamberlain Ranch were not included in the 2014 and 2015 orders because they were under senior water rights. Nonetheless, because this is an area where *E. coli* exceedances have been measured, a means of better controlling the amount of water applied to the land could reduce return flows.

Figure 44. New flume and flow measurement device on irrigation diversion

2016 NRCS approved Conservation Plan for Chamberlain Ranch

Monitoring results for several recreation seasons indicated that there was considerable bacteria loading to the river from irrigated pastures at the Chamberlain Ranch area. In 2013 the Trust for Public Land facilitated the process of putting 258 acres of land upstream from Zion National Park into a conservation easement that is held by the Utah Department of Food and Agriculture. In an effort to ensure proper land management a conservation plan was developed for the property. The final plan includes recommendations for crop production, irrigation improvements, grazing management, orchard improvement and soil improvement. It is expected that implementation of the plan will lead to improvements in water quality downstream of the property.

Trial suspension of grazing at Chamberlain Ranch

In 2016 the landowner of Chamberlain Ranch opted to not graze livestock on their pastures to see if water quality improved below the property. Monitoring monthly from May through October showed that there were no exceedances of the chronic or acute water quality standards during that period.

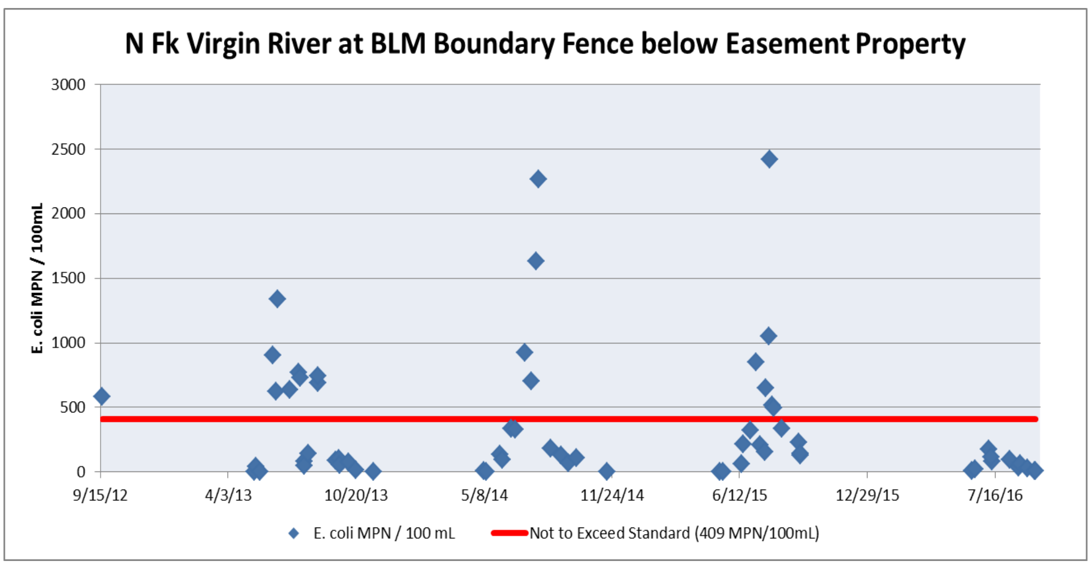


Figure 45: *E. coli* concentrations below Conservation Easement property

7.2 Best Management Practice Considered and Rejected

Beginning in 2011 stakeholders explored the possibility of a pressurized irrigation system being constructed in the upper North Fork Virgin watershed. The expectation was that it would benefit water quality by reducing return flows while at the same time benefitting landowners with increased ease of operation and maintenance. A permanent diversion structure was proposed just upstream of the North Fork Road bridge and location of the current brush and rubble diversion. The system included installation of settling ponds, piping of the unlined canals, and a mix of gated pipe and sprinklers for water delivery onto the pastures.

The area was surveyed and a system design was developed with input from Utah Association of Conservation Districts staff and Natural Resources Conservation Services engineers. Ultimately the project was rejected for several reasons.

First, the river is prone to high flow events during spring runoff and fall monsoons so engineers questioned the long term stability of a permanent in-channel diversion structure. Second, the river frequently carries large sediment loads which would challenge even the best designed and maintained system. And ultimately the project was rejected because the cost/benefit was too high. Bids were over $1 million for a system to irrigate 80 acres of pasture. Stakeholders raised concerns that that option should not be pursued before other more cost effective measures were explored.

7.3 Additional Recommended Best Management Practices

While the BMPs that have been installed have helped make drastic improvements in water quality, additional work is recommended throughout the entire watershed. The following Best Management Practices (BMPs) have been demonstrated to improve water quality in streams affected by high *E. coli* concentrations. These BMPs are not presented in any order of priority, and their effectiveness will be evaluated as part of the monitoring and evaluation phases of the implementation process:

1. Improve/Increase Streamside Vegetated Buffers (Contour Buffer Strips 332)
   - Animals and humans are discouraged from entering vegetated area once it is established. The area between the vegetated buffer and stream filters bacteria from runoff from adjacent land.
   - Consider improving stream crossing at trailhead to encourage hikers to follow the road for the first several miles of the hike.
2. Analysis of Septic Systems
   - Reducing *E. coli* loading from human sources due to failing septic systems should be a priority because of its health implications. This component could be implemented through education on septic tank pump-outs as well as a septic system repair/replacement program and the use of alternative waste treatment systems.

- If outhouses with the potential to impact water quality are identified they will be reported to the local health department office.

3. Irrigation System Improvements (Irrigation Water Management 449)
   - Where feasible look into transitioning flood irrigation systems to more efficient systems that result in less irrigation return flow to the river. (Sprinkler System 442)
4. Riparian Fencing (Fence 382)
   - Eliminates direct defecation in the stream and prevents the trampling of the stream banks and riparian vegetation.
5. Outreach/Education Programs
   - Inform the public of the importance of good water quality and the risks associated with recreating in waters where *E. coli* standards are not being met.
   - Encourage proper waste management for pets, humans and livestock.
   - Improve signage at the narrows trail head, directing hikers to use the road and not to follow the river. The easement riparian area is being impacted by hikers.

7.3 Future Monitoring

Follow-up monitoring is required to ensure implementation efforts result in the attainment of water quality standards. The Utah Division of Water Quality, in collaboration with other stakeholders, will continue to collect *E. coli* samples where and when appropriate to evaluate the effectiveness of pollution control efforts.

The current plan is for continued *E. coli* monitoring at several of the established monitoring locations. Sites previously identified as non-supporting on the Utah 303(d) list will have to be monitored until full support status is reached in order for the assessment unit to be delisted for *E. coli*. Those sites include:

4951260	N Fk Virgin River at North Fork Road Bridge (Not impaired but used as a control monitoring location above flood irrigated pastures where exceedances have historically been measured)
4951263	N Fk Virgin River at Narrows Trailhead
4951272	N Fk Virgin River at BLM Boundary Fence
4951268	N Fk Virgin River at End of Road
4951199	N Fk Virgin River at Temple of Sinawava

Many pathogen studies include a microbial source tracking (MST) component to determine through genetic analysis the sources of bacteria in the river. MST techniques can often help determine if the source is human, wildlife, or domestic animal. The analysis is expensive and not 100% conclusive so it has not been used yet as part of the North Fork Virgin River study. There is fairly good consensus among the stakeholders that the bacteria source is a combination of human, wildlife and domestic animals, and that the primary source during the recreation season is flood irrigation of pastures conveying fecal matter to the river. Based on preliminary results it is anticipated that irrigation system improvements and changes in grazing management will result in water quality standards being met for the North Fork Virgin River.

7.4 Public Involvement

Stakeholder participation for this TMDL process was achieved through meetings and site visits with state and federal agency representatives and landowners.

North Fork Virgin River stakeholders include:

- Utah Division of Water Quality
- Utah Department of Agriculture and Food
- Zion National Park
- Bureau of Land Management – Kanab Field Office
- Utah Farm Bureau
- Utah Division of Water Rights
- Utah Association of Conservation Districts
- US Forest Service - Dixie National Forest
- Southeast Utah Health Department
- Natural Resources Conservation Service
- Iron and Enterprise Conservation District
- Utah State University Extension
- Private landowners

The first site visit was held on November 19, 2009. Representatives from DWQ, National Park Service, Kanab Field Office BLM and Utah Association of Conservation Districts participated. The goal was to familiarize everyone with the upper watershed, the monitoring locations and the results. A subsequent stakeholder group site visit took place on September 9, 2011. Between 2012 and 2017 agency and landowner stakeholders have been onsite many times for monitoring, to observe current land use practices, and for discussions of potential best management practices.

Public education and involvement is critical to the success of any TMDL development and implementation effort. To that end the first public meeting was on April 7, 2010 in the Nature Center at Zion National Park. Agenda items included an introduction to water quality and *E. coli*, a discussion on ordinances dealing with human waste, and a discussion of proper grazing management principles and Best Management Practices. The second public meeting was on November 29, 2010 in Cedar City. The change in location was made in an attempt to better facilitate landowner participation. The purpose of that meeting was to review monitoring results from the 2010 recreation season, as well as discuss irrigation practice alternatives and Best Management Practices. Additional public meetings took place on June 12, 2012 in Cedar City and April 19, 2016 in Springdale.

Meetings with agency representatives were conducted on October 12, 2012, March 12, 2015 and April 19, 2016.

The draft TMDL was presented at a public meeting in Springdale on December 19, 2017. Stakeholder comment period began December 20, 2017. Comments were due January 19, 2018. X comments were received (Appendix A). Public comment for the TMDL was solicited with a public notice on X, 2018 via the Salt Lake Tribune Newspaper, The Spectrum Newspaper, and the Utah Division of Water Quality (DWQ) website (www.waterquality.utah.gov).

Part of Utah's TMDL process includes presenting the TMDL to the Water Quality Board after the 30-day public comment period to request rulemaking to formally adopt the TMDL. The North Fork Virgin River *E. coli* TMDL was presented to the Board on January 24, 2018. A 30-day DAR public notice period occurred from February 15, 2018 to x, 2018. The Board formally adopted this TMDL into rule on x, 2018. The TMDL has been submitted to EPA for final approval.

REFERENCES

Barcina, I. J.;Gonzalez, M.; Iriberri, J.; Egea L. (1990) Survival Strategies of *Escherichia coli* and *Enterococcus faecalis* in Illuminated fresh and Marine systems. *J. Appl. Bacter*. **68**,189-198.

Benham, B.L.; Baffaut, C.; Zeckoski, R.W.; Mankin, K.R.; Pachepsky, Y.A.; Sadeghi, A.M.; Brannan, K.M.; Soupir, M.L.; Habersack, M.J. (2006) Modeling Bacteria Fate and Transport in Watersheds to Support TMDLs. *Transactions of the ASABE*. **49**(4):987-1002.

Christensen PK, Hughes JC, Hansen WR. Ground Water Discharge from the Navajo Sandstone to the Streamflow of the Virgin River in the Zion National Park Area. National Park Service.

Easton, J. H.; Gauthier J. J.; Lalor, M.; Pitt, R. E. (2005) Die-off of Pathogenic *E. coli* in Sewage Contaminated Waters. *AWRA Journal of the American Water Resources Association*, **41**, 1187-1193.

Jamieson, R. C.; Joy, D. M.; Lee, H.; Kostaschuk, R.; Gordon, R. J. (2004) Persistence of Enteric Bacteria in Alluvial Streams. *J. Environ. Eng. Sci.*, **3**, 203–212.

Kistemann, T.; ClaBen, T.; Koch, C.; Dangerndorf, F.; Fischeder, R.; Gebel, J.; Vacata V.; Exner, M. (2002) Microbial Load of Drinking Water Reservoir Tributaries during Extreme Rainfall and Runoff. *Appl. Environ. Microbiology*., **68**, 2188-2197

Leclerc, H.; Mossel, D. A. A.; Edberg, S. C.; Struijk, C. B. (2001) Advances in the Bacteriology of the Coliform Group: Their Suitability as Markers of Microbial Water Safety. *Annual Review of Microbiology*, **55**, 201-234.

Rose, J.B.; Sun, G.; Allen, C.P., and N.A. Sinclair. Microbial Quality and Persistence of Enteric Pathogens in Graywater from Various Household Sources. Journal of Water Resources, Volume 25, No 1. 1991.

State of Colorado Department of Public Health and Environment and U.S. Environmental Protection Agency, Region VIII (2011). Boulder Creek, Colorado Segment 2b: From 13th Street to the Confluence with South Boulder Creek Escherichia coli Total Maximum Daily Load (TMDL) Prepared for: City of Boulder, Colorado and January 5th, 2011.

Steen-Adams M. Applying Environmental History to Ecological Restoration: A Case Study from Zion National Park. Ecological Restoration December 2002;20(4):252. Available from: Academic Search Premier, Ipswich, MA. Accessed August 29, 2013.

US Forest Service. North Fork Virgin River Suitability Evaluation Report. US Forest Service. http://www.fs.usda.gov/Internet/FSE_DOCUMENTS/fsbdev3_014964.pdf. 2008. Accessed August 29, 2013.

Utah Department of Environmental Quality, Division of Water Quality. Accessed June 8, 2011. Utah Bacteriological Monitoring Program: Bacteriological Standards. http://www.waterquality.utah.gov/Monitoring/Bac/methods.htm.

Utah Department of Environmental Quality (2016) Utah's 2016 Integrated Report and 303(d) List of Impaired Waters. Department of Environmental Quality, Division of Water Quality, https://deq.utah.gov/ProgramsServices/programs/water/monitoring-reporting/assessment/docs/2016/chapter-3-river-and-stream-assessments-final2016ir-v2-1.pdf

Utah Division of Administrative Rules (2005) R317-2: Standards of Quality for Waters of the State. Utah State Bulletin, Vol. 2005, No. 1.

Utah Division of Administrative Rules (2005) R317-2: Standards of Quality for Waters of the State. Utah Administrative Code: Effective February 1, 2006. http:/./www.rules.utah.gov/publicat/code/r317/r317-002.htm#T15.

Zeckoski, R. W., Benham, B. L., Shah, S. B., Wolfe, M. L., Brannan, K. M., Al-Smadi, M., Dillaha, T. A., Mostaghimi, S., and C.D. Heatwole. 2005. BSLC: A Tool for Bacteria Source Characterization for Watershed Management. American Society of Agricultural Engineers ISSN 0883-8542. Vol. 21(5): 879-889.